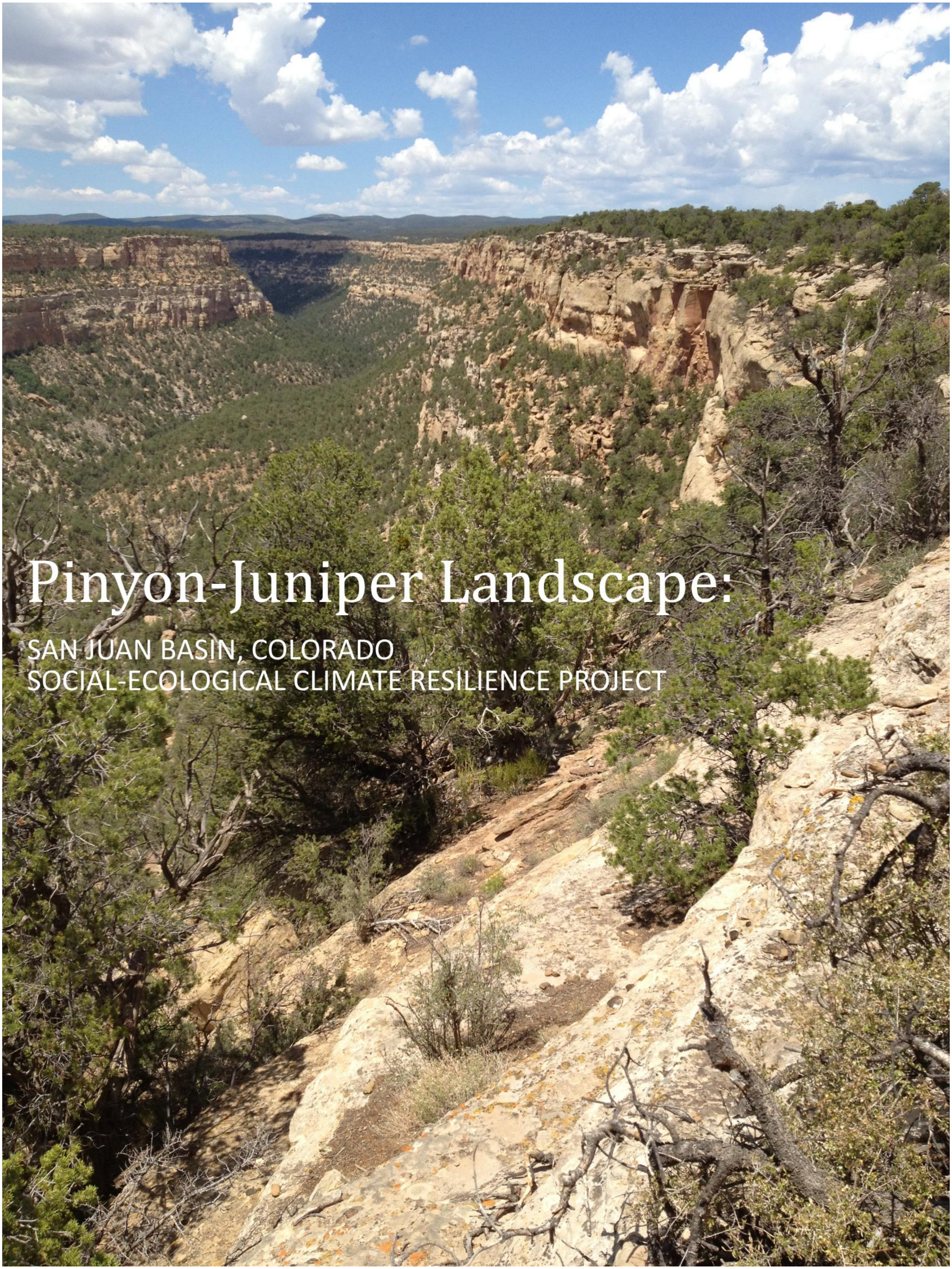

Pinyon-Juniper Landscape:

SAN JUAN BASIN, COLORADO
SOCIAL-ECOLOGICAL CLIMATE RESILIENCE PROJECT

DRAFT FINAL REPORT FOR REVIEW

Report Prepared for:

North Central Climate Science Center, Fort Collins, Colorado

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Front Cover Photo: Navajo Canyon, Mesa Verde National Park (R. J. Rondeau)

Pinyon-Juniper Landscape: San Juan Basin, Colorado Social-Ecological Climate Resilience Project

EXECUTIVE SUMMARY

Climate change is already having impacts on nature, ecosystem services and people in southwestern Colorado and is likely to further alter our natural landscapes in the coming decades. Understanding the potential changes and developing adaptation strategies can help ensure that natural landscapes and human communities remain healthy in the face of a changing climate.

An interdisciplinary team consisting of social, ecological and climate scientists developed an innovative climate planning framework and worked with the Social-Ecological Climate Resilience Project (SECR) and other stakeholders in Colorado's San Juan River watershed to develop adaptation strategies for two significant landscapes, pinyon juniper woodlands and seeps, springs, and wetland resources under three climate scenarios between 2035 and 2050. This report summarizes the planning framework and results for the pinyon-juniper landscape (the seeps, springs and wetlands results will be provided separately). This framework can be utilized to develop strategies for other landscapes at local, state, and national scales.

Diagrams, narrative scenarios, and maps that depict climate scenarios and the social-ecological responses help us portray the climate impact in the face of an uncertain future.

Interviews and focus group workshops with agency staff and stakeholders who are users of public lands identified several important opportunities to improve the adaptation planning process for developing strategies that meet both social and ecological needs. Planning techniques that include or directly relate to specific resources, such as water and forage, or to activities, such as recreation or grazing, provide avenues for engaging diverse stakeholders into the process.

Utilizing the scenarios to understand the impacts to our social and ecological landscapes, three overarching landscape-scale adaptation strategies were developed. Each of these strategies has a suite of potential actions required to reach a desired future condition.

The three key strategies are: 1) identify and protect persistent ecosystems as refugia, 2) proactively manage for resilience, and 3) accept, assist, and allow for transformation in non-climate refugia sites.

If the framework and strategies from this project are adopted by the local community, including land managers, owners, and users, the climate change impacts can be reduced, allowing for a more sustainable human and natural landscape.

ACKNOWLEDGEMENTS

This project would not have been possible without the participation of the San Juan Climate Initiative, an informal public-private partnership that has been working since 2006 to prepare for change in the San Juan Mountain region, including the San Juan Basin in Colorado.

We thank the many stakeholders, agencies, consultants and representatives of the academic community who participated in a series of workshops, interviews, and focus groups over the past three years. Additionally, we offer a special thanks to George San Miguel, Mesa Verde National Park, and Gretchen Fitzgerald and Kelly Palmer, San Juan National Forest, Tomoe Natori, Ute Mountain Ute Nation, who also provided agency insight and reviewed many products and reports to make the project more relevant to our partners. Their years of effort within their agencies and communities to initiate climate conversations provided an opening for this project to take root and flourish.

We greatly appreciate funding, programmatic and technical support from the Department of Interior's (DOI) North Central Climate Science Center in Fort Collins, Colorado. We are equally grateful for the funding provided by Bureau of Land Management Tres Rios Field Office and San Juan National Forest to support the vulnerability assessments that provided an initial foundation. In addition, we thank the Rocky Mountain Research station for providing additional support for the social scientist interviews and focus groups.

We also appreciate the technical support of cooperators on this project from the University of Colorado, Wildlife Conservation Society, Western Water Assessment/NOAA, Colorado State University, and US Geological Survey, specifically Nina Burkardt and Rudy Schuster, who graciously guided the project. We want to thank Betsy Neely, The Nature Conservancy and the Gunnison Climate Working Group for sharing this initiative with the San Juan group, as we learned a lot from working in concert with the two watersheds. The exchange of ideas and experiences greatly enriched our project in the San Juan watershed.

Special thanks to Jim Worrall, US Forest Service, for providing guidance on the bio-climatic models and to Karin Decker, Colorado Natural Heritage Program, for formatting this report. The chain of consequences and results chains methods were initiated by Kristen Ludwig and Teresa Stoepler, US Geological Survey, and Terri Schulz of The Nature Conservancy. Special thanks to Chris Rasmussen, Ecosystem Mainstream Consultants, Stephen Monroe, National Park Service Inventory and Monitoring Program, Nicole Barger, University of Colorado, Kris Johnson, University of New Mexico, and Lynn Wickersham, Animas Biologic for technical contributions. Thanks to San Juan National Forest and Mesa Verde National Park for providing meeting space and reviewing this document. Finally, thanks to Jeff Morisette and his staff at North Central Climate Science Center, for helping to assemble the great team that it took to accomplish this project.

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ACRONYMS

ACT	Adaptation for Conservation Targets planning framework
BLM	Bureau of Land Management
CNHP	Colorado Natural Heritage Program
CSU	Colorado State University
CU	University of Colorado- Boulder
DOI	Department of Interior
FLC	Fort Lewis College
MEVE	Mesa Verde National Park
MSI	Mountain Studies Institute
NCCSC	North Central Climate Science Center
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
PJ	Pinyon-Juniper
RCP	Reflective Concentration Pathways
SECR	Social-Ecological Climate Resilience Project
SJCI	San Juan Climate Initiative
SJNF	San Juan National Forest
SSW	Seeps, springs and wetlands, a landscape target system of this project
SUIT	Southern Ute Indian Tribe
SUIT BIA	Southern Ute Bureau of Indian Affairs
TNC	The Nature Conservancy
UM	University of Montana
UMUT	Ute Mountain Ute Tribe
USFS	United States Forest Service
USFS RMRS	United States Forest Service Rocky Mountain Research Station
USGS	United States Geologic Survey
US	United States
WCS	Wildlife Conservation Society
WWA	Western Water Assessment

INTRODUCTION

Environmental change is a constant feature of land management within the US Intermountain West. Fire, drought, insect infestations, and invasive species present pervasive challenges to the conservation and management of western lands. Southwestern Colorado is already experiencing higher temperatures, more frequent and prolonged drought, earlier snowmelt, larger and more intense fires, more extreme storms, and spread of invasive species (Saunders et al. 2008). These are all changes that are expected to intensify as a result of climate change putting livelihoods, ecosystems, public lands, and species at risk.

Climate change poses significant challenges for both ecological systems and human communities in southwestern Colorado. Resource managers need to consider climate change in management decisions and long term planning. Yet, while they are increasingly being tasked to incorporate climate change in management decisions, many barriers and challenges exist that complicate integrating climate information and producing robust adaptation strategies. Climate change information is often at the global scale and projected over long time periods and this makes it difficult for managers to integrate it into local management plans with shorter timescales. Furthermore, the uncertainty of how climate will change, especially in hard-to-model mountainous landscapes, increases the difficulty of this task and the risk of taking any particular approach.

The Social-Ecological Climate Resilience Project (SECR) was formed to address these challenges. Over three years, a team of social, ecological and climate scientists and planners worked with the San Juan Climate Initiative, a public-private partnership working to prepare for change in Colorado's portion of the San Juan River and Dolores River watersheds (referred to in this report as the San Juan Basin), natural resource management agencies, and other stakeholders, This collaborative effort has developed practical adaptation strategies for selected systems in the San Juan Basin. The team was led by the Colorado Natural Heritage Program (CNHP), Mountain Studies Institute (MSI), University of Montana (UM), and U.S. Geological Survey (USGS). Another team led by The Nature Conservancy (TNC) and CNHP led a parallel effort in the Gunnison Basin for spruce–fir forest and sagebrush scrub landscapes.

The goal of the SECR project was to facilitate climate change adaptation that contributes to social-ecological resilience, ecosystem and species conservation, and sustainable human communities in southwestern Colorado. This project has developed and piloted an integrated adaptation planning framework, consisting of tools and principles that merge the strengths of the iterative scenario process, the Adaptation for Conservation Targets (ACT) planning framework, institutional analysis, and climate change modeling.

The framework was used to generate practical strategies and scientific knowledge to advance climate change adaptation in the San Juan and Gunnison Basins and, potentially, other landscapes. A key objective of this project was to work with decision-makers to develop social-ecological adaptation strategies and coordinate actions to reduce the impacts of a changing climate on nature and society. In order to accomplish this, SECR blends science from biophysical and social disciplines with participatory approaches to integrate expert knowledge, land management decision making, and local needs.

An adaptation target is a feature (livelihood, species, ecological system, or ecological process) of concern that sits at the intersection of climate, social, and ecological systems (adapted from Cross et al. 2012). Resilience is the capacity of a system to absorb disturbance and still retain its basic function and structure. Resilience strategies may include managing for the persistence of current conditions, accommodating change and transformation, or managing towards desired new conditions (Department of Interior NPS 2016). These and other terms are defined in the glossary (Appendix A).

Intended implementers of the adaptation strategies are the stakeholders and participants who participated in the project process over the past three years: natural resource managers, local landowners, non-profit organizations, local government officials, and others.

Project Objectives

1. Build knowledge of social-ecological vulnerabilities to inform adaptation planning.
2. Create social-ecological scenarios and models to facilitate decision-making under uncertainty.
3. Develop a detailed set of actionable and prioritized adaptation strategies designed to conserve key species, ecosystems, and resources, and to address the needs of local communities and natural resource managers.
4. Identify the adaptive capacities and the institutional arrangements needed to advance these strategies into decision-making arenas.
5. Document best practices for effectively bringing climate science into decision-making.

Deliverables

1. Innovative, effective, integrated social-ecological adaptation planning tools and principles that can be applied in other landscapes.
2. Narrative scenarios of landscape change in southwestern Colorado and conceptual ecological models (ecological response models) that can be used in adaptation planning.
3. Summary reports on interview and focus group results.
4. An institutional analysis.
5. A set of actionable adaptation strategies for priority ecosystems that include specific conservation/adaptation targets and action steps/paths to implementation.
6. Reports and manuscripts focused on adaptation decision-making and adaptive capacity, institutional analysis, and results and lessons learned from an integrated adaptation framework.
7. Guidelines and a toolkit for practitioners to employ integrated adaptation planning in other landscapes.

Funding

This project was funded by the Department of Interior's (DOI) North Central Climate Science Center (NCCSC), Fort Collins, Colorado. Matching funds from Bureau of Land Management (BLM) Tres Rios

Field Office and the San Juan National Forest (SJNF) supported the vulnerability assessments for ecosystems, vulnerable species, and rare plants that complimented this effort. Rocky Mountain Research Station provided additional support for the social science.

Project Team

The project team consists of representatives of CNHP, MSI, TNC, UM, U.S. Geological Survey (USGS), Western Water Assessment (WWA)/ National Oceanic and Atmospheric Administration, Colorado State University (CSU), US Forest Service - Rocky Mountain Research Station (RMRS), University of Colorado (CU), and University of Cincinnati.

San Juan Basin Partners

Key partners and stakeholders participating in this project include the San Juan Climate Initiative, an informal public-private partnership working to prepare for change in the Colorado portion of the San Juan Basin consisting of the Mesa Verde National Park (MEVE), SJNF, BLM-Tres Rios Field Office, Ute Mountain Ute Tribe (UMUT), and Southern Ute Indian Tribe (SUIT) and Bureau of Indian Affairs (SUIT BIA). See Appendix B for full list of participants at the workshops.

Overview of Planning Framework and Process

Planning Framework Key Steps

1. Select socio-ecological landscapes to be the focus of the project and conduct literature search regarding natural processes, climate impacts
2. Develop three plausible climate scenarios
3. Develop ecological response models to help understand impacts under three climate scenarios to inform development of robust adaptation strategies for the targeted landscapes
4. Develop three narrative scenarios for participatory workshops
5. Conduct social science research through interviews and focus groups
6. Develop social ecological response models to identify impacts and interventions using Situation Analysis and Chain of Consequences
7. Hold a series of workshops to develop and refine adaptation strategies to address current and future climate vulnerabilities, utilizing Results Chains method.

Landscape Selection

In December of 2013, the SECR partners selected the pinyon-juniper landscape and seeps, springs and wetlands as the focus of this project because of their social, economic, and ecological importance to the San Juan Basin. Criteria considered included: vulnerability rank from San Juan/Tres Rios Climate Change Ecosystem Vulnerability Assessment (Decker and Rondeau 2014), nested species and rank from Sensitive Species Assessment of Vulnerability to Climate Change on San Juan Public Lands (Rhea et al. 2013), opportunity for success in building resilience, social concerns and livelihoods that benefit from the ecosystem services, relevance to decision makers regarding upcoming management decisions, available data, biodiversity values, and wildlife values.

Three Climate Scenarios

Uncertainties in the future climate present managers with challenges and opportunities. To help in decision-making for a range of future conditions, Imtiaz Rangwala, Western Water Assessment, University of Colorado, developed attributes associated with three climate scenarios for southwestern Colorado and the Gunnison Basin for the year 2035. He used a base of 72 models and 2 Representative Concentration Pathways (RCPs 8.5 and 4.5) and then identified three potential clusters that represented different future pathways for the project. The scenario clusters represented three different plausible futures – a hotter drier future, a warmer future where annual precipitation increases, and a future with high inter-annual variability between hot dry years followed by cold wet years. The climate scenarios are named respectively: 1) Hot and Dry; 2) Warm and Wet; and 3) Feast and Famine (Appendix C). The Feast and Famine climate scenario predicts more frequent and intermittent severe-drought conditions, large year-to-year fluctuations that range from "hot and dry" to "warm and wet" conditions, and a doubling in the frequency of alternating extreme dry and wet conditions relative to the present (Appendix D).

Renée Rondeau, CNHP, researched the potential ecological impacts of the three climate scenarios to the targeted landscapes. This information was used to develop a set of ecological response models and narrative scenarios to assist managers in developing social-ecological adaptation strategies under the three climate scenarios.

Ecological Response Models

The team, working closely with natural resource managers, developed reference condition and ecological response models for the pinyon-juniper landscape in the San Juan Basin. The purpose of ecological response models was to help evaluate potential impacts of the three climate scenarios on the two landscapes in the San Juan Basin. The team held a series of small group work sessions between January and March, 2015 to develop draft preliminary reference models and ecological response models for the landscapes. Participants included representatives from CNHP, MSI, MEVE, SJNF, CU, CSU, NCCSC, WWA, and private ecological consultants. On March 3rd, 2015, the team hosted a workshop with San Juan Basin experts to review and refine ecological response models to help evaluate potential impacts of three climate scenarios on the landscape in the Gunnison Basin. Participants included representatives from MEVE, SJNF, BLM Tres Rios Field Office, Southern Ute Indian Tribe (SUIT) and Bureau of Indian Affairs (SUIT BIA), Ute Mountain Ute Tribe (UMUT), and private ecological consultants. Ecological response models are in Appendix E.

Narrative Scenarios

Renée Rondeau (CNHP) and Imtiaz Rangwala (WWA) drafted three narrative scenarios for the San Juan Basin that described plausible landscape changes that could take place over the next 20 years. The scenarios were descriptive stories that depicted potential changes in the landscape based upon the climate scenarios that are referred to as "Hot & Dry," "Warm & Wet," and "Feast & Famine." The narrative scenarios were developed for use during the focus group workshops for the social science research. They were reviewed by the SECR team and subject experts familiar with the ecology and local systems. The experts' comments were incorporated into the final narrative tool that was used in workshops led by our social scientists (see Appendix F).

Social Science Interviews

Carina Wyborn, College of Forestry and Conservation, UM, and Marcie Bidwell, MSI, reached out to agencies, partners and members of the ranching community to conduct in-depth semi-structured interviews to understand their perspectives on landscape changes in the San Juan Basin (Wyborn et al. 2015). The interviews queried stakeholder's perceptions of current conditions and impacts, future conditions as envisaged under a changing climate, management approaches, capacity to realize goals, and decision making in the face of uncertainty.

Fieldwork was conducted from April through July 2014. Dr. Wyborn conducted 34 in-depth, semi-structured interviews with ranchers and public land managers at three agencies[1]. Results were audio-recorded and transcribed verbatim to assist in analysis. Transcripts were then coded using Nvivo software. Coding was used to identify themes and facilitate analysis. The results were summarized in a separate report (Appendix F).

Narrative Scenario Workshops

Two workshops were conducted between June 24th and July 10th, 2014. The goal of the workshops was to explore possible future changes that might take place in the San Juan Basin over the next 20 years and to understand the impact of those changes on land management in the region. SJNF hosted the first workshop, which focused on the Glade Landscape, an area being evaluated through a grazing landscape analysis. This workshop was attended by 17 USFS employees and 11 permittees from the Glade Landscape. The second workshop was hosted by MEVE to discuss the intersection of pinyon-juniper woodlands within a national park management setting. This workshop was attended by 12 NPS employees. A secondary goal of the workshops was to introduce participants to a process that can be used to support decisions in the context of uncertainty. Each workshop was centered on the three narrative scenarios described above (Hot and Dry, Warm and Wet, and Feast and Famine; Appendix C). Scenarios were presented individually and then followed by a series of questions regarding anticipated impacts, management needs, conflicts, compromises and potential strategies.

Socio-Ecological Response Models

The team worked with stakeholders to integrate social and ecological responses of climate change on the pinyon-juniper landscape using two different approaches: Situation Analysis and Chain of Consequences.

The Situation Analysis approach defines the context within which a project is operating and, in particular, the major forces influencing the biodiversity of concern at a site, including the direct and indirect threats, opportunities, and scope (Foundations of Success, 2009). The process of developing a Situation Diagram (Appendix G) helps teams create a common understanding of the biological, environmental, social, economic, and political systems that affect targeted landscapes. This method has been used around the world by the Conservation Measures Partnership, TNC, and others.

The DOI Strategic Sciences Group developed the Chains of Consequences method for teams of scientists to identify the potential short- and long-term environmental, social, and economic cascading consequences of an environmental crisis and to determine intervention points to aid decision-making. The method has been used to identify the consequences and potential interventions of the Deep Water Horizon oil spill in the Gulf of Mexico and Hurricane Sandy (DOI Strategic Sciences Working Group 2010, 2012; Department of the Interior, 2013).

See Appendix H for the Situation Analysis and Appendix I for Chain of Consequences results.

Stakeholder Workshops

The Team hosted a series of workshops with the San Juan Climate Initiative and other stakeholders from March 2015 through May 2016 to identify climate impacts to the landscapes under the three climate scenarios, identify interventions (preliminary adaptation strategies), develop social-ecological models, and develop adaptation strategies. These workshops are summarized below.

May 2015 Climate Adaptation Strategy Workshops

To prepare participants for the workshops, the team held a series of pre-workshop webinars on the following topics: 1) three climate scenarios; 2) ecological response models for sagebrush and spruce–fir forest landscapes; 3) methods for identifying preliminary interventions; and 4) preliminary results of social science interviews and focus groups. The team also developed a participant packet of materials including an agenda, materials produced to date, description of methods, and the approach for facilitating discussion focused on climate change.

The team hosted a workshop on May 5th, 2015 in Durango to develop social-ecological climate response models for pinyon-juniper woodlands and seeps, springs and wetland resources; identify a suite of preliminary intervention points and potential high-level adaptation strategies for one climate scenario; and prepare for a fall workshop to develop in-depth adaptation strategies (from Phase I). Due to time constraints, this workshop focused only on one climate scenario, Feast and Famine, with the intention of addressing the two other scenarios at future workshops. The workshop provided an opportunity to compare two methods (Situation Analysis and Chain of Consequences) for developing interventions and identifying preliminary adaptation strategies.

The May 2015 workshop was the first of several workshops to develop social-ecological adaptation strategies for the pinyon-juniper landscape for three climate scenarios in the San Juan Basin. The outcomes included: 1) integrated findings from climate models, ecological response models and social science to produce social-ecological response models for the Feast and Famine climate scenario (one of three climate scenarios); 2) comprehensive list of preliminary interventions that provide a foundation for developing more in-depth adaptation strategies for the targeted landscapes under three climate scenarios; and 3) improved stakeholder buy-in for developing and implementing local and regional interventions and adaptation strategies. Products of the meeting can be found in Appendix H and I.

The Team hosted a series of workshops with the San Juan Climate Initiative and other stakeholders from March 2015 through May 2016 to identify climate impacts to the landscapes under climate scenarios, identify interventions (preliminary adaptation strategies), develop social-ecological models, and develop adaptation strategies. These workshops are summarized below.

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March 2016 Climate Adaptation Workshops

At the March 1st 2016 workshop, stakeholders reviewed the management goals and interventions that were developed for the different scenarios at the 2015 workshops. The interventions were reviewed for a set of three climate adaptation strategies for the pinyon-juniper landscape. The participants helped to prioritize the intervention points to inform the development of strategies at the next meeting.

April 2016 Climate Adaptation Workshops

The April workshop developed draft adaptation strategies. We utilized the results of the intervention points to create *Results Chains* or diagrams for three overarching strategies that depict causal linkages between strategies and desired outcomes needed to reduce climate change impacts and other threats. The process creates a logic diagram by describing a sequential series of expected intermediate outcomes and actions necessary to achieve the desired outcomes (Margoluis 2013). This process helped to build a common understanding of the outcomes and actions needed to reduce the impacts of climate change for each strategy.

The objectives of the final workshops held in April 2016 were to: 1) review and refine goals/objectives for the pinyon-juniper landscape; 2) develop social-ecological climate-smart strategies to prepare the landscapes and the people who depend on them for increased drought, wildfire, and other associated climate impacts; and 3) identify challenges and opportunities to ensure successful implementation of strategies. Following the workshop, the team revised the Results Chains based on the feedback at the meeting and turned the diagrams into bulleted text to summarize each of the strategies, including desired outcome, intermediate outcomes, and actions.

Workshop Participants

Workshops included participants from federal, state, and local government agencies, academia, non-profit organizations, and the private sector. Participants included land and water managers, wildlife biologists, ecologists, foresters, researchers, planners, professors, social scientists, county officials, and other stakeholders. Participants included representatives from BLM, CNHP, Colorado Parks and Wildlife, Colorado State Forest Service, MEVE, National Park Service, TNC, MSI, Natural Resources Conservation Service, New Mexico Heritage Program, SUIT, SUIT BIA, CU, New Mexico Forest Service, SJNF, and private consultants.

THREE CLIMATE SCENARIOS FOR THE FUTURE

Climate Scenario Summaries

Projected changes in temperature and precipitation by 2035 for the three climate scenarios are shown in Figure 1, and the consequences of these changes summarized by scenario below. See Appendix C for a table comparing the three climate scenarios.

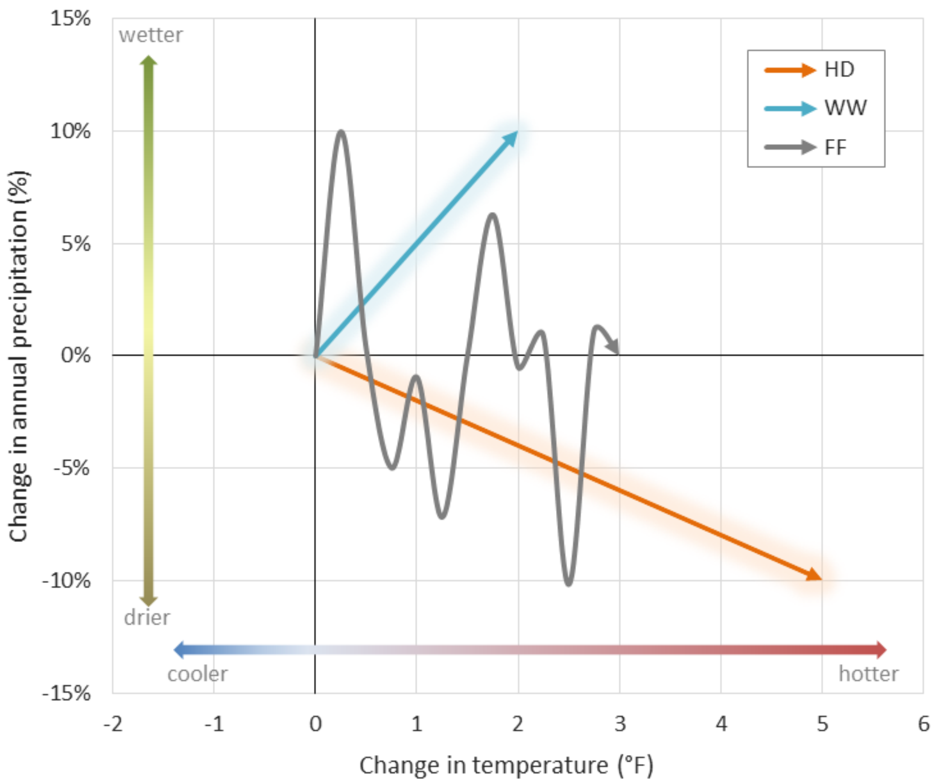

Figure 1. Generalized depiction of change in annual precipitation and temperature for three climate scenarios (Hot and Dry, Feast and Famine, and Warm and Wet).

Hot and Dry (hadgem2-es.1.rcp85)

Average annual temperatures are 5°F higher than now, combined with a decrease in annual precipitation of 10%, produces drier conditions year-round. Summers at lower elevations are expected to have 30 additional days with temperatures above 77°F (25°C) and many nights with lows of 68°F or above. Heat wave conditions are severe and long lasting. Rain events are likely to be less frequent, but more intense, and summer monsoon rains decrease (20% less than recent historic levels). Droughts comparable to 2002 or 2012 occur on average every five years.

Hot and dry conditions lead to:

- Longer growing season (+3 weeks), reduced soil moisture, increased heat stress
- Higher elevation of permanent snowline (+1200 ft)
- Frequent extreme spring dust-on-snow events
- Earlier snowmelt and peak runoff (+3 weeks, earlier with dust events). Decreased runoff (-20%)
- Longer fire season (+1 month) greater fire frequency (12x) and extent (16x) in high elevation forest

Feast and Famine (Moderately Hot/No Net Change in Precipitation, cesm1-bgc.1.rcp85)

Average annual temperatures are 3°F higher than now and increased magnitude of inter-annual fluctuations in precipitation levels produce generally drier conditions, especially during the growing season, but some years with strong El Niño patterns may be quite wet. Summers at lower elevations are expected to have 14 additional days with temperatures above 77°F (25°C) and many nights with lows of 68°F or above. Heat wave conditions are common every few years. Strong El Niño events can be expected every seven years on average, while droughts comparable to 2002 or 2012 occur on average every decade. During wetter years, increased temperatures lead to increased vegetation growth and subsequent greater fuel loads for wildfire.

A “feast or famine” pattern fluctuating between hot/dry and warm/wet conditions leads to:

- Longer growing season (+2 weeks)
- Higher elevation of permanent snowline (+900 ft)
- Increased extreme spring dust events in dry years
- Earlier snowmelt and peak runoff (+2 weeks, earlier with dust events). Decreased runoff (-10%)
- Very high fire risk during dry years following wet years, greater fire frequency (8x) and extent (11x)

Warm and Wet (cnrm-cm5.1.rcp45)

Average annual temperatures are 2°F higher than now, combined with an increase in net annual precipitation of 10% produce generally warmer but not effectively wetter conditions in comparison with recent historic levels. Summers at lower elevations are expected to have 7 additional days with temperatures above 77°F (25°C). Heat wave conditions may occur once a decade. Droughts may be more intense, but with fewer instances of extended drought.

Warmer and slightly wetter conditions lead to:

Extended growing season (+1 week)

Higher elevation of permanent snowline (+600 ft)

Occasional extreme spring dust events in dry years, comparable to current conditions

Earlier snowmelt and peak runoff (+1 week). No change in runoff volume

Increased fire frequency (4x) and extent (6x)

SOCIAL-ECOLOGICAL VULNERABILITIES

As part of the SECR Project, twenty-six agency staff from three agencies and eight grazing permittees were interviewed about landscape changes in the San Juan Basin. Interviews focused on changes to pinyon-juniper woodlands and seeps, springs, and wetlands as the resource targets. Questions also explored climate change, adaptation and uncertainty in land management. See Appendix F for the full report summarizing the interviews.

Key Findings

Both agency staff and permittees envisioned changes to these systems in terms of impacts to specific resources (e.g. water and forage) and activities (e.g. recreation). For agency staff from the BLM and USFS in particular, pinyon-juniper was the location for key management activities (e.g. gazing, oil and gas, and recreation) and not managed for specific ecosystem features. Similarly, permittees focused on rangeland conditions and the management of grazing permits in pinyon-juniper. For most of the NPS interviewees, the management of pinyon-juniper revolves in part around questions about appropriate fire management and different views on how to best conserve the human infrastructure of the park (both contemporary and historic dwellings) and less often to conserve the ecosystem itself. Like some from MEVE, BLM and USFS participants suggested that they were unsure of the "natural" state of pinyon-juniper, questioned what the management goals for the system should be and wondered whether pinyon-juniper is a "climax" community or one that is encroaching on other communities that are valued more highly (i.e. sagebrush). For all participants, changes to seeps, springs, and wetlands were seen as important and raised concerns about water availability for a range of human uses, including grazing and recreation. Permitees also expressed concerns about long-term drought, the timing of their on-off dates, staff turnover within the agencies, communication with the agencies, and the length of time taken to receive permission to undertake actions related to their permits.

Participants had different views of what climate adaptation might mean in the San Juan Basin. Both agency staff and permittees conveyed that they had a limited capacity to extend beyond current activities. For the agency staff, this meant that they were unsure of the extent to which they could take on extra climate adaptation activities. Limited capacity for adaptation was linked to budget and staffing constraints. In particular, inadequate resources for monitoring translated into a lack of understanding of how the system and resources are changing over time, depriving the process of knowledge necessary to assess the efficacy of adaptation efforts. In the context of uncertainty and incomplete knowledge, agency staff discussed drawing on a broad, interdisciplinary group of specialists to form a more complete picture to inform decision-making. Uncertainty was believed to promote a risk-averse, conservative approach to decision-making within the agencies.

Given these findings, effective climate adaptation on federal lands in the San Juan Basin may benefit from incorporating climate impacts into future management decisions, thereby benefiting people and nature.

Conclusions

Based on interviews with 34 agency staff and permittees, we found the following:

- There was widespread awareness about climate change and recognition that climate change would impact target systems and that these impacts needed to be addressed. However, most participants felt challenged to effectively deal with climate impacts due to uncertainty and limited knowledge and resources.
- The focus on ecological targets enabled in-depth discussion of particular systems and insights into how management agencies and permittees think about and manage these systems. However, this focus did not produce detailed understanding of broader social vulnerabilities as they relate to climate change.
- The focus on ecological targets did enable us to uncover a critical disconnect between the adaptation literature and the way agencies actually manage public lands. In short, most agency managers address specific short-term activities that occur on an individual site (e.g. grazing, recreation, forestry, fire management) rather than specific long-term ecological targets within those systems.
- Thus, for adaptation within seeps, springs and wetlands and pinyon-juniper woodlands in the San Juan Basin to be effective, decision makers need to understand how on-the-ground activities impact the ecological values. One way to do so is to integrate climate impacts and adaptation strategies into management decisions. Such an approach would:
    - Leverage existing resources. All participants expressed concerns about their lack of capacity to pursue additional management activities related to climate adaptation. Integrating adaptation into existing management activities (e.g. range management, silviculture, etc.) might provide a mechanism to leverage existing resources and increase overall capacity for adaptation action.
    - Integrating vulnerable species and ecosystems into on-the-ground management and monitoring would likely improve the knowledge of the ecological value and ecosystem services. There was widespread agreement that agencies do not manage for the ecological values of pinyon-juniper or seeps, springs, and wetlands per se, but rather focus on specific management activities within these systems, with an understanding that these activities influence ecological processes and individual species. Further, improved monitoring was seen as critical for effective adaptive management.
    - Resonate with the public and key stakeholders. Federal agencies will likely find more support for adaptation actions if these actions are meaningful to local community members. A focus on the uses and values of the landscape that people care about may help build support for adaptation.
- Efforts to prepare federal land management agencies for climate adaptation may also need to consider the following:
    - Effective responses to climate change may require that the concept of climate adaptation be well-defined and mainstreamed in the agencies. We found that agency staff had very different definitions of climate adaptation and many participants were uncertain about the relationship between adaptation and land management.
    - Adaptation efforts need to be cognizant of the ways that uncertainty influences agency decision-making. Agency staff are accustomed to dealing with uncertainty,

but tend more toward conservative, risk-averse strategies and longer decision-making processes as uncertainty increases.

- Climate change may drive system transformations in some places, but many agency staff are just beginning to consider the possibility of transformative change and the social and technical challenges that this presents to management.
- The notion of managing for a range of climate impacts is not yet well-established in agency decision-making. It is important to provide useful information about how scenarios and other tools can be used to consider different possible futures and integrate uncertainty into management decisions. At the same time, efforts to integrate new processes, such as scenarios into decision-making need to consider the increased analysis burden.
- More work is needed to determine how to adapt decision-making processes to enable more nimble management. In particular, lengthy decision timeframes and NEPA processes may present barriers to effective climate adaptation.
- Agencies and different stakeholder groups, such as permittees, may benefit from dialogue regarding the knowledge that would assist in decision making.
- Dialogue processes that enable managers and stakeholders to share knowledge might also help address disagreements regarding the value and vulnerability of pinyon-juniper. Building a common understanding of the ways that climate change potentially impacts pinyon-juniper may be important to enable adaptation efforts in response to changes in this system.

DESCRIPTION OF PINYON-JUNIPER LANDSCAPE AND ECOSYSTEM SERVICES

The pinyon-juniper landscape in the San Juan Basin occupies warm, dry foothills, mesas, canyons, plateaus, and mountain slopes and consist of a mosaic of vegetation types, with the pinyon-juniper woodlands dominating the majority of the area. These woodlands are generally a mix of pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*), and at upper elevations or in mesic areas, the Rocky Mountain juniper (*J. scopulorum*) can dominate in stands that grade into ponderosa pine woodlands. At the upper and wetter elevations pinyon pine dominates while at the lower and drier elevations juniper dominates and pinyon pine may be sparse or absent (Figure 2). Smaller, scattered patches of other plant communities occupy the landscape including: sagebrush shrublands, oak and mixed-mountain shrubland, desert grassland, wet meadows and groundwater dependent wetlands. Elevations are generally between 5,400 and 7,650 ft. Annual precipitation is about 12-23 inches, with a mean of 17.2, similar to the range of sagebrush shrubland. These evergreen woodlands are adapted to cold winter nighttime temperatures and low rainfall and typically occupy areas between lower elevation desert grassland/shrubland and higher elevation montane conifer ecosystems. At upper elevations pinyon-juniper woodlands mix with oak shrublands or ponderosa pine woodlands and at lower elevations it adjoins desert grasslands and desert shrublands. This system is not a fire adapted system; crown fires have a 200-400 year fire return interval. This landscape consists of nearly one million acres (930,000 acres) within the San Juan Basin in Colorado; ownership includes tribal (40%), BLM (30%), USFS (4%), NPS (2%), and private (25%). The landscape is exceedingly rich with cultural resources, in large part due to pinyon and juniper providing raw materials to native tribes including important food, shelter, fuel, and medicine.

Numerous species in the San Juan Basin rely on a functioning pinyon-juniper landscape that may be at risk of degrading with the future climate. Nearly 25 bird species depend on this habitat type (Salaz and Wickersham, 2016) and include Pinyon jay, Gray vireo, and Juniper titmouse, which are all pinyon-juniper obligates and regarded as sensitive species. A number of other birds nest in tree cavities. Sensitive mammals in this habitat include Gunnison prairie dog, Merriam's turkey, Fringed myotis, Hoary bat, and Spotted bat. These woodlands are also important habitat for larger game animals including mule deer and elk (important for local traditional tribal use), especially during winter.

A number of rare plant species (G1-G3) occur within this landscape, including Chapin Mesa milkvetch, Cliff Palace milkvetch, Gypsum Valley cateye, Naturita milkvetch, Mancos milkvetch, Mesa dropseed, Mesa Verde stickseed, Mesa Verde aletes, Eastwood milkvetch, Violet milkvetch, Paradox breadroot, Wetherill's milkvetch, Aztec milkvetch, Jones blue star, Little penstemon, Weak-stemmed mariposa lily, and Knowlton's cactus.

Ecosystem services provided by the pinyon-juniper landscape include livestock grazing, hunting, pinyon seed harvest, firewood, agriculture, wildlife habitat, forest products, recreation including mountain biking and hiking, and carbon sequestration and storage in the face of a changing climate.

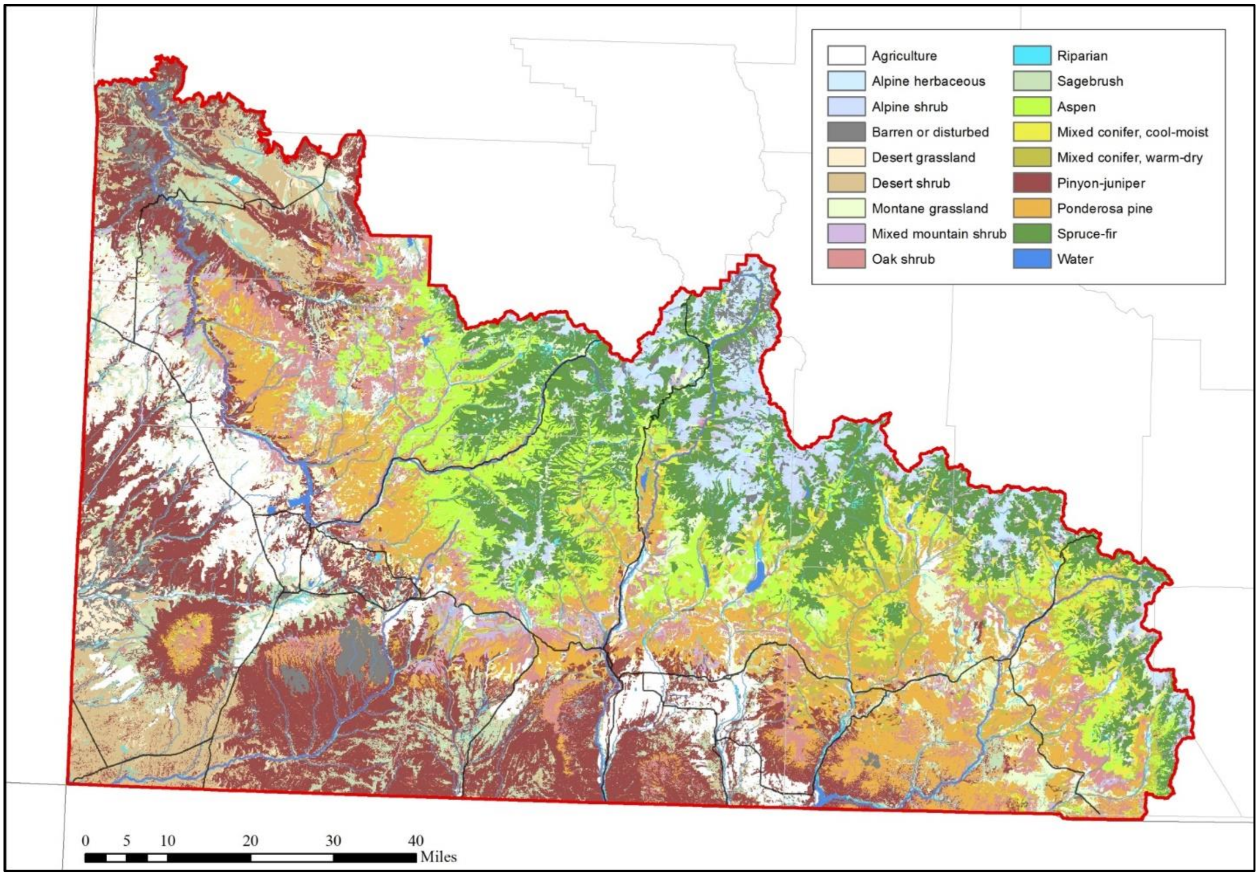

Figure 2. Major ecosystems of the San Juan Basin, CO (SWReGAP, USGS 2004).

CLIMATE CHANGE IMPACTS AND ECOLOGICAL RESPONSE MODELS

Ecological Response Models

Response models are conceptual tools to describe how the landscape operates and provides a context for evaluating potential impacts of different climate scenarios. The models help identify outside environmental influences or drivers. They help visualize the relationships among the main contributing factors that drive one or more of the direct threats that, in turn, impact the landscape. The current and ecological response models for pinyon-juniper, based on literature review, local knowledge and expert opinion, describe how the landscape operates and provides a context for evaluating potential impacts of different climate scenarios. The purpose of assessing the landscape under three different climate scenarios is to provide a foundation of scientific understanding of the range of possible futures and to inform the development of robust social-ecological adaptation strategies for pinyon-juniper in the face of an uncertain future. See Appendix E for diagrams of the ecological response models for the reference condition and under three climate scenarios.

Below are general descriptions of the current Reference Condition and a snapshot of the future pinyon-juniper landscape under each of the three climate scenarios.

Reference Condition Model

The Reference Condition Model is based on the LANDFIRE state-and-transition model with adjacent systems added (LANDFIRE 2007). LANDFIRE developed state-and-transition models to represent pre-settlement reference conditions for all ecological systems in the United States through an expert-based model development process. Each model represents a single ecosystem. LANDFIRE used the models to estimate reference conditions, which are used to help assess ecosystem health.

A typical reference condition model starts with early successional grassland moving to early successional woodland, moving through mid-successional open and closed canopy forests to late-successional open and closed canopy woodland. Replacement fires move the woodland back to early successional stage. Insects, disease, small-patch fires, and drought will move the closed canopy woodland types to open conditions and younger stands when older trees are killed. Given enough time without major fires, trees will eventually dominate the system. It is important to note that large scale fire return intervals occur over centuries, not decades as in the ponderosa pine zone. The pinyon pine tree does not produce abundant seed until it is nearly 75 years old and trees cannont survive fires. Pinyon pine is a masting species and generally produces a good cone crop approximately every seven years. A cone requires 26 months to form and unfavorable conditions (hot and dry) will cause the seeds to abort.

Hot and Dry Climate Scenario

This scenario generally results in extreme drying and decreased soil moisture. A projected increase in winter and spring soil moisture recharge may be beneficial for tree survival, but a decreased monsoon is likely to have a negative impact on cone production. Mast-years will be much less frequent and seed germination and establishment of pinyon greatly reduced. Warmer temperatures in late summer will reduce pinyon cone crops. Warmer winters and warmer summers are favorable for the pinyon engraver beetle (*Ips confusus*) beetle outbreak. Droughts like 2002 will occur every five years on average. While lower elevation stands (below 6,000 ft) are most at-risk for tree mortality, the upper elevations are still likely to be effected. Because juniper is more tolerant of drought, the species composition of these woodlands will shift toward a predominance of juniper and loss of pinyon. Fire seasons will start earlier and end later, and fires are expected to be more frequent and larger. Stand-replacing fires will be common. Insect outbreaks and diseases will be at their highest rates in this scenario due to the higher temperatures. *Ips* beetle mortality is greater on older, larger, cone-producing pinyon and less on younger trees. Large scale loss of pinyon seed sources may decimate Pinyon jay populations, greatly reducing the retention and recovery of pinyon pines. Cheatgrass and other invasive species are likely to dominate after a large fire and may impair succession back to a woodland.

Feast and Famine (Moderately Hot) Climate Scenario

On average, a 3% increase in winter-summer soil moisture recharge is projected, but also a 3% decrease in monsoon recharge. Soil moisture deficits are expected in “famine” years. Although pinyon pine mast years could occur during wet “feast” years, warmer summer temperatures may inhibit cone formation, while seed germination and establishment is likely to be reduced if multiple wet years are uncommon. Juniper is likely to increase in frequency over pinyon pine. Favorable conditions for pinyon-juniper will move up into the zone currently occupied by ponderosa pine. However, large scale loss of pinyon seed sources may reduce Pinyon jay populations, greatly reducing the ability of pinyon pines to remain in their present locations or colonize new areas. Warmer winters and warmer summers are favorable for *Ips* beetle outbreaks, and tree mortality will be enhanced in drought years. During dry years, wildfire scope and severity will increase, driven in party by fuel build-up in preceding wetter years. More large-patch fires will kill more trees. In general the area currently occupied by pinyon-juniper woodlands in the San Juan Basin will decrease and be replaced by grassland and shrubland types. Overall, this scenario may produce similar results as a hot and dry scenario, albeit at a slower pace.

Warm and Wet Climate Scenario

In this scenario there is an approximate 10% increase in soil moisture recharge projected over all seasons. Moisture levels should be sufficient to maintain cone production and masting, if other factors, such as cool and wet falls, are favorable. Drought years like 2002 will be similar to current frequency and should not dramatically affect the pinyon to juniper ratio. The fire frequency will be similar to the current regime, where small-patch fires are most common. There is a chance that this scenario is favorable for a pinyon pine-juniper expansion rather than a contraction that would occur with the other two scenarios.

IMPACTS AND INTERVENTIONS

In order to focus our attention on the most robust and large-scale adaptation strategies for the pinyon-juniper landscape, we refined, categorized, and filtered the list of impacts and intervention points developed at the previous workshops (see Appendix J). These priority intervention points were used as starting points for strategy development to address the three climate scenarios.

Questions

To assist us with filtering and prioritizing the impacts and interventions, we asked three primary questions:

1. Which impacts are most likely to be significant across all climate scenarios?
2. Which intervention points are most likely to be sussesful across all three climate scenarios?
3. Which intervention points are likely to work at a landscape-level scale?

Methods

In order to answer the above questions, we organized the interventions by the impacts that they addressed. We devised a process to score and prioritize the impacts and their interventions by their anticipated significance, likelihood across all scenarios, and landscape scale (Large, medium, or small). Impacts and interventions with a high score denoted significant impacts and interventions and would be the focus of our adaptation strategies workshop. We devised a ranking spreadsheet to maintain the scores, summarized in Tables 1-2. Thus the strategies on which we would focus were: 1) likely to be effective in reducing climate impacts at a large landscape-level scale and 2) likely to be effective across three climate scenarios.

Table 1. Top impacts to the pinyon-juniper landscape across the three climate scenarios. The higher the score, the greater the scope and severity of the impact across all three climate scenarios.

Impact	Score
Altered species composition	10
Altered forest structure	10
Altered fire regime	7
Attitudes/Public awareness	5
Decreased soil health and function	3
Elevated fire risk	2
Social and economic forest management	2

Table 2. Intervention categories with total score and landscape scale. The total score is a sum of the intervention and impact scores. Generally there were multiple impacts and interventions associated with an intervention category, thus we took the average. The total score, coupled with scale, was used to define which intervention categories would be the focus of our adaptation strategy workshop. The bolded intervention categories became our strategies. Cross-cutting denotes the need to subsume these interventions into all strategies.

Intervention Category	Average of Total score	Average of Intervention Score	Average of Impact Score	Scale
Accept, assist and allow transformation	12.0	7.0	5.0	Large
Research and monitoring	11.8	6.0	5.8	Cross-cutting
Cross boundary coordination	11.0	6.0	5.0	Cross-cutting
Identify and protect refugia	11.0	6.0	5.0	Large
Education and outreach	10.7	5.0	5.7	Cross-cutting
Proactive treatment for forest resilience	10.2	4.7	5.5	Large
Proactive fire management	10.1	5.1	5.0	Large

The final three strategies identified for further development were:

1. **Protect and identify refugia (persistent areas)**: protection, management and restoration are much more likely to succeed if they occur within a climate refugia
2. **Proactive management for resilience**: this strategy had numerous interventions and generally mirrors much of what managers are already doing. It is most likely to succeed in areas that are considered "refugia"
3. **Accept, assist and allow transformation**: it is important to recognize that transformation is likely to occur, e.g., pinyon-juniper may slowly colonize into new areas (emergent areas), and wildfire may rapidly convert large stands into a different ecosystem (threatened or decreasing areas).

GOALS AND OBJECTIVES FOR PINYON-JUNIPER LANDSCAPE

Goal

In the face of a changing climate, protect and maintain a resilient landscape that includes pinyon, juniper, mountain shrublands, sagebrush, grasslands, and other small patch types that supports viable populations of target plant and animal species of concern, and supplies our human communities with a suite of ecosystem services, including clean water, recreation, tourism, hunting, food and shelter, carbon sequestration, and forest products. Healthy populations of pinyon-juniper obligate species are a good indicator of the functioning ecosystem. In 2035 we will still have a mosaic of resilient pinyon-juniper woodlands, primarily associated with climate refugia (persistent) zone. This zone will allow for natural colonization into upper elevation zones that do not currently support pinyons and junipers. In addition, we will prepare for a potential loss or degradation of pinyon-juniper woodlands in areas that are unlikely to have a suitable climate for regeneration. The managed mosaic of emergent, persistent, and decreasing pinyon-juniper zones will allow natural processes to occur and will have adequate representation of functioning seeps, springs, and wetlands.

- Protect and maintain large, interconnected, functional, and resilient pinyon-juniper landscapes that support persistent populations of pinyon-juniper obligate species, human livelihoods, and human ecosystem services including clean water, recreation opportunities, hunting, food and shelter, carbon sequestration.
- Maintain and restore desired hydrologic functions and vegetation in riparian areas and wet meadows to benefit wildlife while enabling ranchers to adapt to climate change.
- Maintain pollinators that provide important ecosystem services.
- Enhance the resiliency of pinyon-juniper ecosystems to climate change by maintaining ecological processes, and restoring and/or improving the condition of the pinyon-juniper communities to support a variety of wildlife species, while offering ecosystem services including livestock grazing, recreation, and the production of forest and non-forest products.
- Manage human uses on the landscape (e.g., recreation, residential development, grazing, ranching, energy development, water systems, mining, roads, and research) in ways that benefit the health of the land and native species and maintain landscape functionality and ecosystem services.
- Reduce the impacts of stressors that will be exacerbated in a changing climate.
- Accept that some species are vulnerable and difficult to maintain in their current position/site. Allow and assist transformation within the emergent and lost zones when possible.
- Reduce soil erosion associated with climate change driven alternations, and protect soil crusts.

Objectives

1. By 2035, conserve areas identified as pinyon-juniper climate refugia and linkages that represent potential refugia and habitat connectivity within the San Juan Basin for pinyon-juniper obligate species (e.g., Pinyon jay, Gray Vireo, and Juniper titmouse). Healthy Pinyon jay populations will serve as an indicator for functioning pinyon-juniper woodland.
2. By 2035, on appropriate ecological sites, increase the native understory component of pinyon-juniper communities and maintain cover to sustain structure and function and improve habitat for small mammals.
3. By 2035, where pinyon-juniper is vulnerable and where climate suitability is likely to change, facilitate a type conversion to suitable habitats.
    - Facilitate transition into juniper savannas at lower ecotones and transition of pinyon-juniper into ponderosa pine at upper ecotones.
4. By 2035, ensure that a variety of pinyon age classes are maintained across the landscape and within climate refugia stands.
5. Maintain old growth juniper and pinyon stands, especially if they are within refugia areas.
6. Design and build new infrastructure (roads, powerlines, culverts, etc.) to resist more frequent high-intensity climatic events, e.g., wildfires and catastrophic floods.
7. By 2035, reduce the impact of invasive species such as cheatgrass so that pinyon-juniper systems are more resilient to climate change.
8. By 2035, improve degraded watershed conditions and restore degraded habitat within pinyon-juniper landscape, including degraded riparian sites and wetland acres.
9. Protect identified archeological/cultural resources from erosion.
10. Maintain land management practices that retain sustainable human use of pinyon and juniper services, e.g, nut harvest, juniper posts, grazing, and residential occupancy.
11. By 2035, implement management practices on degraded sites that will increase carbon storage and improve wildlife habitat, utilizing climate-smart practices.

Adaptation Strategies, Outcomes and Actions for Pinyon-Juniper Landscape

The climate adaptation strategies for the pinyon-juniper landscape are presented below in both tabular format and results chains. These strategies incorporate all of the information gathered over the course of this project, e.g., climate scenarios, social response to interviews and narrative scenarios, ecological response models, situation analyses, chain of consequences, and identification of interventions.

Three Priority Adaptation Strategies for the Pinyon-Juniper Landscape

<table>
<tr><th>Adaptation strategy</th><th>Bio-climatic zones*</th></tr>
<tr><td>Identify and Protect Refugia (persistent areas)
We can identify and manage the areas that are most likely to persist under our future climate. Conservation, management, and restoration are much more likely to succeed if within a climate refugia.</td><td rowspan="2">Persistent & Threatened
Persistent areas are the “refugia” or areas that are likely to retain a suitable climate for pinyon-juniper.

Threatened areas may continue to support trees, but the future climate is marginal and may hinder regeneration.</td></tr>
<tr><td>Proactive Treatment for Resilience
These strategies allow us to develop treatment/ restoration plans that will improve the resiliency of the pinyon-juniper landscape, especially within those areas that are likely to be persistent.</td></tr>
<tr><td>Assist and Allow Transformation
It is important to recognize that transformation is inevitable and rather than resist this change, we will accept the change, and even assist in the inevitable transformation.</td><td>Lost & Emergent
Lost areas represent parts of the pinyon-juniper landscape where the future climate is highly unlikely to support pinyon-juniper woodlands and are most likely to transform into a grassland or some other non pinyon-juniper community once a large disturbance removes the trees.

Emergent areas represent parts of the pinyon-juniper landscape where we believe the future climate will support pinyon-juniper habitat, but the area does not currently support pinyon and juniper trees.</td></tr>
</table>

*Bio-climatic zones are mapped in Appendix K.

Strategies are summarized and depicted in results chains below.

Strategy 1: Identify and Protect Persistent Ecosystems

Desired Outcome
Pinyon-juniper persists within refugia and linkages are maintained. Populations of obligate species and human livelihoods thrive.

Identifying, protecting, and managing patches that are likely to persist in the face of climate change will assist in maintaining a resilient pinyon-juniper landscape that supports viable populations of species of concern and supplies our human communities with a suite of ecosystem services.

►Intermediate outcomes ✧Actions to achieve outcome

Refugia are persistent communities that are likely to support current ecosystems into the future.

- ► Biophysical attributes that are in persistent pinyon-juniper landscape are identified
  - ✧ Identify fragmentation factors, keeping scale in mind Include intactness, fragmentation, condition among patches (critical for refugia linkages)
  - ✧ Consider the interplay of fragmentation with fire, drought, and invasives
  - ✧ Consider regeneration cycle for pinyon pine
  - ✧ Identify soils with high water-holding capacity (NRCS soil maps)
  - ✧ Identify cultural values and sites
  - ✧ Identify existing species management areas that support refugia
  - ✧ Biophysical attributes may include slope, aspect, elevation, and topographic factors
- ► Linkages identified between persistent areas that support pinyon-juniper ecosystems and viable populations of obligate species
  - ✧ Consider pinyon and juniper regeneration, including seed dispersal by Pinyon jays
  - ✧ Shrub component within pinyon-juniper is important for linkages
  - ✧ Map the character of Pinyon jay habitat
  - ✧ Create maps of potential refugia and linkages
  - ✧ Identify attributes: patch size, canopy closure, stand age, mortality
  - ✧ Conduct ground-truthing, research, and monitoring
- ► Education and outreach shared with public and private land managers
  - ✧ Conduct education and outreach
  - ✧ Awareness and information is made available to land managers
  - ✧ Offer on-the-ground training workshops
- ► Private land supporting persistent pinyon-juniper identified and preserved through conservation easements
  - ✧ Conduct private land assessments
- ► Viable livelihoods maintained
  - ✧ Ranching livelihoods: Identify compatible grazing levels in refugia
  - ✧ Cultural tourism: Consult tribal members regarding sensitive areas / refugia
- ► Management targeted within refugia to maintain a more resilient pinyon-juniper
  - ✧ Reduce non-climate stressors
  - ✧ Set policy and management decisions about:
    - ▪ Soil and forb disturbance from grazing

        - Recreation soil disturbance
        - Forest product removal
        - Roads and fire break fragmentation
        - Oil and gas fragmentation
        - Invasive species
    - ✧ Understand the conflict between conifer obligate species and sage grouse needs
    - ✧ Identify ecological sites that support sagebrush and pinyon-juniper

Why this Strategy is Important

Persistent ecosystems, i.e., refugia, are areas likely to support the pinyon-juniper landscape into the future. The scale of linkage zones may vary depending on the species, e.g., large for elk and deer, smaller for Pinyon jay, and species genetics. How you manage the land depends on what linkages are proposed to be facilitated. The refugia sites are likely to maintain a suite of ecosystem services that will benefit human communities, e.g., livestock grazing, snow retention, flood mitigation, recreation, hunting, etc.

Challenges to Implementation

The key challenges to implementing this strategy are: 1) public understanding and/or acceptance, buy-in on the need for refugia, and finding willing landowners; 2) funding to protect and manage these areas; 3) existing policies provide sideboards as to what kinds of management can occur and may not easily allow the needed management; 4) push back from fire management goals; 5) a comprehensive understanding of pinyon pine seed production, seed dispersal and germination, and seedling survival as it relates to climate variables 6) *Ips* beetle impact to pinyon pine populations.

Opportunities for Successful Implementation

The key opportunities for implementing this strategy are: 1) ability to structure conservation easements to accommodate, support and encourage certain types of management; 2) the NPS, BLM, and USFS have mechanisms to work with private lands and implement plans at the landscape scale, 3) opportunities for funding and learning through collaborative field trips, in-person seminars and meetings and workshops, 4) explain the importance of refugia and the need to manage for resilience.

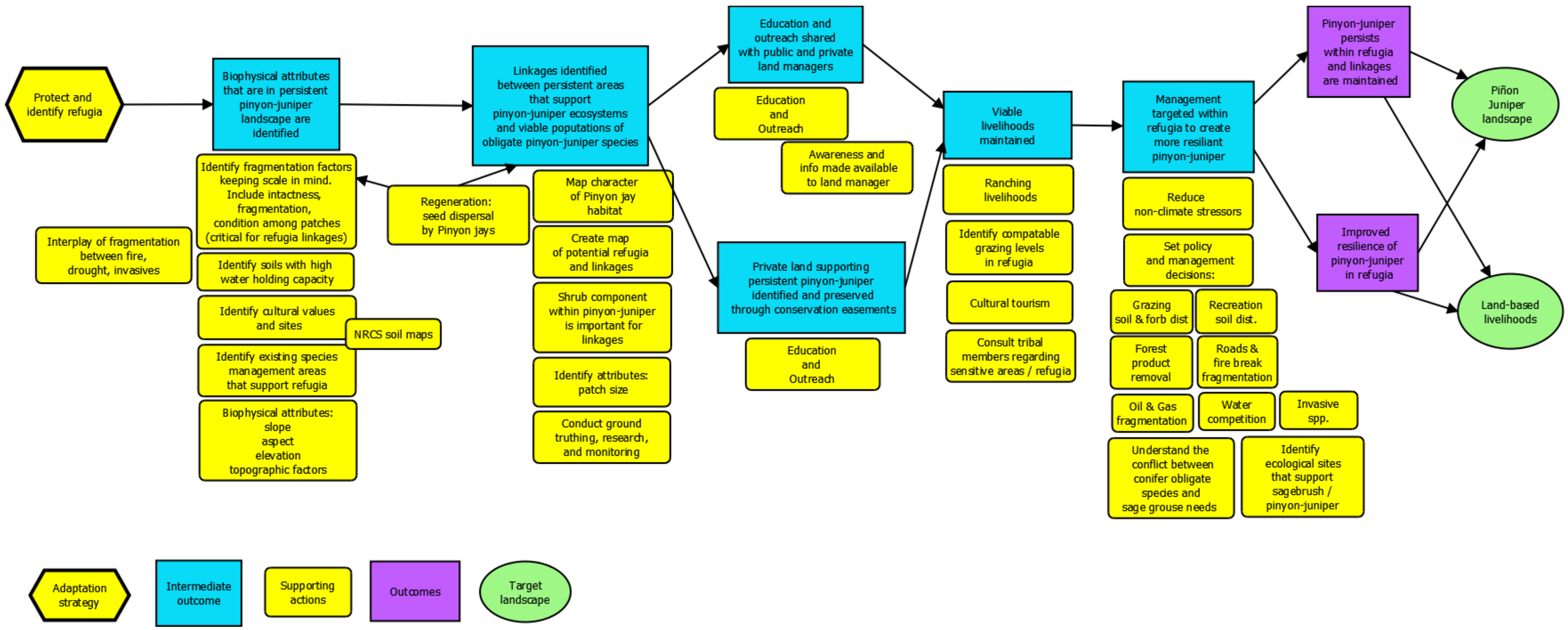

Figure 3. Results chain describing outcomes and actions for to identify and protect persistent areas strategy.

The blue and purple colors need to be toned down to a pastel. The dark shade makes it too hard to read.

Strategy 2. Proactive Management for Resilience

Desired Outcome

Enhance the resiliency of pinyon-juniper communities in climate refugia by maintaining ecological processes and healthy soils.

Maintaining ecological processes, restoring and improving the natural conditions, and reducing climate stressors may increase the resiliency of pinyon-juniper ecosystems to sustain traditional, aesthetic, and ecosystem values and services.

▶ Intermediate outcomes ✧ Actions to achieve outcome

- ▶ Hydrologic functioning is maintained
    - ✧ Use innovative structural features and designs to support soil function
    - ✧ Control erosion
- ▶ Soils are stable and functioning
    - ✧ Encourage the presence of more nitrogen-fixing plants and symbionts
    - ✧ Encourage bitterbrush shrubs to enrich soils
    - ✧ Protect biological crusts
    - ✧ Maintain ectomycorrhizal activity
    - ✧ Manage and restore physical disturbance
    - ✧ Maintain burrowing mammals
    - ✧ Where appropriate, maintain or improve native ground cover
- ▶ Native biodiversity is maintained
    - ✧ Identify and maintain genetic diversity
    - ✧ Collect seed from a range of areas and elevational gradients
    - ✧ Develop climate-smart seed mix
    - ✧ Increase bitterbrush and shrubs in restoration seed mixes
- ▶ Invasive species management plan implemented
    - ✧ Create network for sharing BMPs and lessons learned
    - ✧ Invest in research on bacterium that reduces cheatgrass and apply when ready
- ▶ Pinyon cone productivity is maintained
    - ✧ Maintain/protect areas with older (>75 yr old) pinyon pine trees as well as 35-75 yr old trees
- ▶ Variable age classes maintained for seed production by large cone-producing trees
    - ✧ Mastication used sparingly and avoided on cone-producing trees
    - ✧ Fire suppression used on old-growth stands, when possible
    - ✧ Buffer old-growth and create fuel breaks
    - ✧ Develop climate-smart restoration plan for post-fire disturbance
    - ✧ Manage fire to protect seed producers
    - ✧ Reduce spread of cheatgrass and other invasives
    - ✧ Manage for an optimal landscape matrix rather than specific trees or shrubs
    - ✧ Explore and research effectiveness of fire breaks, thinning, crown and vigor dynamics
    - ✧ Develop tool or decision tree for selecting best treatments for post-wildfire mitigation

- ► Carbon is sequestered
- ► Primary productivity is enhanced
- ► Traditional use areas are maintained
    - ✧ Identify important areas and practices
- ► Economic value (tourism, grazing) is maintained
- ► Cultural resources are maintained for traditional spiritual and aesthetic uses
- ► Ecosystem services are maintained
- ► Tree cover provides regulated micro-climates (shade, temperature)

Why this Strategy is Important

This strategy, when coupled with the protecting refugia strategy, leads to a well-maintained and resilient pinyon-juniper landscape that provides the ecosystem services for human and natural communities. It is a critical strategy for promoting the capacity of the system to withstand change, retain vital characteristics and services, and reducing impacts from extended droughts and altered species composition. It is especially important as it relates to non-native weeds, e.g., cheatgrass.

Challenges to Implementation

The key challenges to implementing this strategy are: 1) risk of very large fires that exceed capacity to control them; 2) ability to respond to large disturbances, e.g., collecting enough native seed to restore after a big fire or controlling cheatgrass invasion; 3) existing BLM policies do not allow grass banks in permitting range allotments; 4) grazing reductions on public lands may shift impacts to private lands; 5) determining when to change practices versus waiting for better methods to be developed; 6) weighing benefits of removing juniper and pinyon versus the weed problems this causes; 7) knowing the right treatment, when, where, and how to conduct treatments in order to avoid maladaptation; 8) funding to identify refugia and treatments; 9) lack of public awareness regarding climate change; 10) weed management and follow-up treatment of increasing weeds, e.g., wormwood, Canada thistle, yellow toadflax, and cheatgrass.

Opportunities for Successful Implementation

Opportunities for successful implementation of this strategy are: 1) to develop climate-smart seed mixes to prepare for big disturbances, e.g., fire or drought; 2) find common values with landowners and identify ways to improve habitat and build a more resilient landscape in the face of disturbance such as drought; 3) to develop a network of places for ranchers to move their livestock if they have to move off of public allotments due to a drought or fire; 4) USFS allows grass banks or forest reserves; 5) to work with decision makers on grazing plans; 6) to treat and suppress cheatgrass in small and large-scale disturbances and keep it from spreading into the whole landscape; and 7) to coordinate across boundaries to achieve objectives.

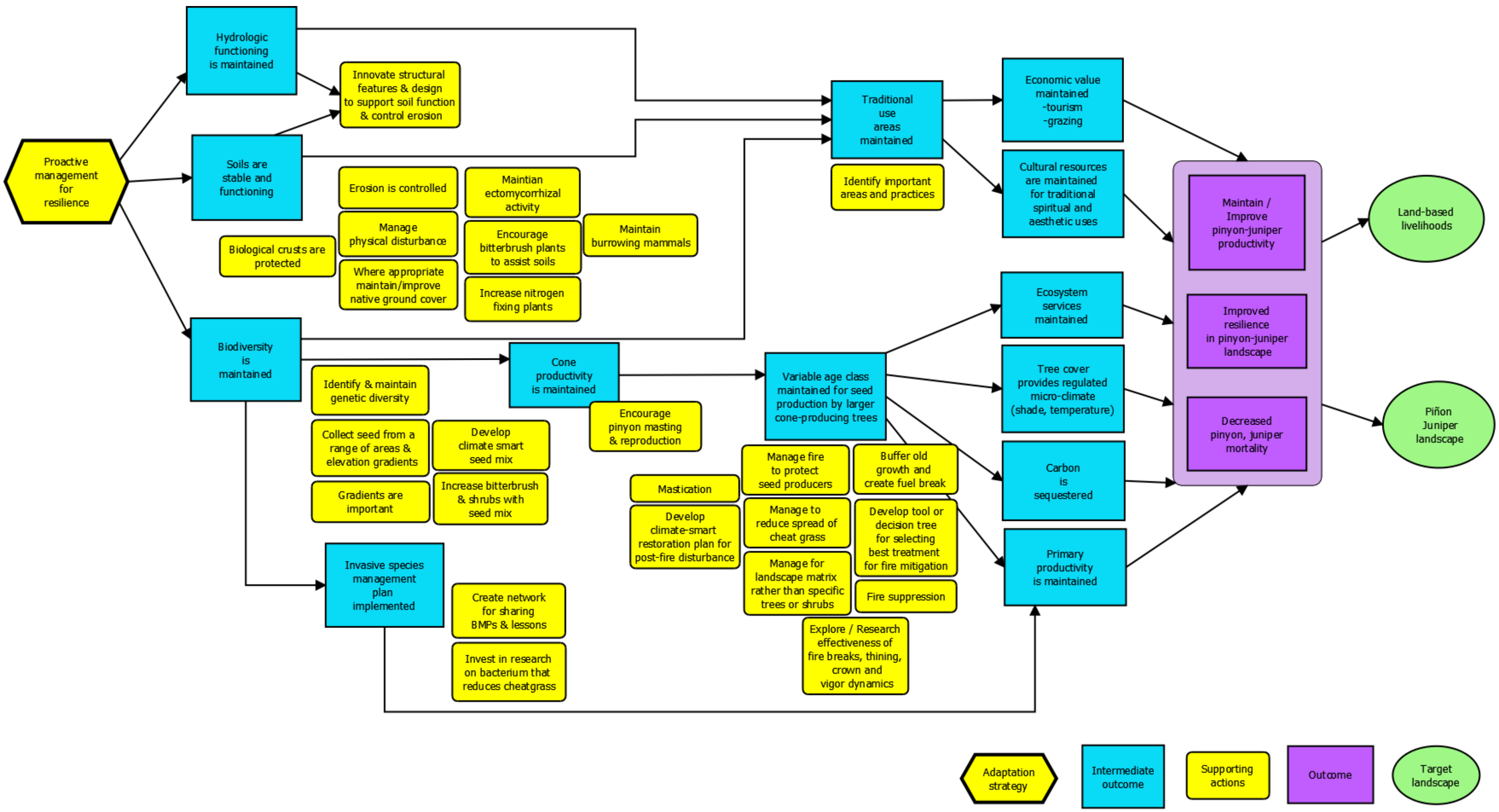

Figure 4. Results chain describing outcomes and actions for proactive treatment for the resilience strategy.

Strategy 3: Assist and Allow Transformation

Desired Outcome

Emergent zones are allowed to transform into pinyon-juniper and lost/threatened zones evolve into functioning and resilient native ecosystems.

In areas where transformation is inevitable, guide resource responses towards desired new conditions and functioning ecosystems that maintain ecosystem services and human uses.

▶Intermediate outcomes ✧Actions to achieve outcome

- ▶ Education and outreach shared with public and private land managers
    - ✧ Develop key messages for general public
        - ✧ Engage early adopters
        - ✧ Develop transformation language and framing
        - ✧ Promote ecological and social value
    - ✧ Develop key managers and offices
        - ✧ Review and update best management practices
        - ✧ Develop trainings for BMP update
        - ✧ Identify key managers who deal with fire and vegetation
        - ✧ Work with fire and water managers
        - ✧ Consult with traditional users
        - ✧ Identify alternative areas
- ▶ Current invasive species and new invaders are controlled
    - ✧ Test cheatgrass control methods
    - ✧ Identify and apply methods to decrease cheatgrass and other invasive species
- ▶ Hot slopes within ponderosa zones allowed to transition to pinyon-juniper
    - ✧ Promote juniper in sagebrush, where applicable
    - ✧ Identify warm refugia close to ponderosa pine
    - ✧ Identify warm, sunny slopes suitable for pinyon-juniper colonization
- ▶ Oak-free zones identified (for non-oak post-fire communities to establish)
    - ✧ Treat understory to encourage pinyon-juniper
    - ✧ Develop climate-smart seed mixes and identify shrubs that are drought and fire tolerant
- ▶ Lower margins of ponderosa zone allowed to have pinyon-juniper
    - ✧ Seed blend is frost tolerant, heat tolerant, and monsoon adapted
    - ✧ Collect seed materials for pinyon at various elevations
    - ✧ Promote "islands" for regeneration sources
    - ✧ Start an experimental nursery
    - ✧ Start nursery stock adapted for climate
    - ✧ Maintain ponderosa to pinyon-juniper linkages

Transformation may occur on two ends of the landscape spectrum, "lost" zone where the climate is unlikely to favor pinyon-juniper regeneration and an "emergent" zones in areas that do not currently have pinyon-juniper but future climate is likely to favor pinyon-juniper. In the "lost" zones we should prepare for a new ecotype, especially following a major disturbance. In the "emergent" zones we should accept "pinyon-juniper expansion" especially in areas that are adjacent to large refugia. See Appendix K for maps.

    - ✧ Plant pinyon in ponderosa after fire
    - ✧ Consider Clark's nutcracker in decisions
- ► Sagebrush transformation promoted in eco-appropriate sites
    - ✧ Identify options for Mancos shale and harsh growing condition sites
    - ✧ Encourage conifer infill if ecological site is appropriate and sage grouse are not present
    - ✧ Plant climate-smart species while conducting restoration
    - ✧ Identify the right plant for the right site
    - ✧ Increase water available for wildlife
    - ✧ Protect and restore seeps, springs in area
- ► Opportunities for new uses considered, i.e., grazing, recreation, wildlife winter range
    - ✧ Plant native grasses and forbs

Why this Strategy is Important:

This strategy is focused on emergent and lost zones of the pinyon-juniper landscape. It is our only strategy that accepts and embraces major changes. These major changes are more likely to occur in the low elevation areas that are currently very dry sites and at the higher elevations where pinyon-juniper can start colonizing upwards. We need to pay special attention to rare plant populations and what managers might be able to do to protect them as they may have no place to go. There may be specific rare plant areas where we research, monitor, adapt, e.g., the Denver Botanic Garden collects seed and plants the seeds where needed. Experimental design and monitoring are needed early on for implementing this strategy and adapting management practices. Adopting climate-smart seed mixes are likely to assist with fire mitigation.

Challenges to Implementation:

The key challenges to implementing this strategy are: 1) agency policies regarding planting seed from outside the region; 2) lack of understanding and awareness about the impacts of climate change as to where and how it will affect ecosystems; 3) losing sagebrush may affect the Candidate Conservation Agreement guidelines for Gunnison sage grouse; 4) accepting pinyon-juniper "invasion" into the emergent zones and accepting sagebrush transformation in the low elevation sites; 5) cultural preferences and values of desired ecosystems may not align with transitioning ecosystems on the ground; and 6) low confidence in our ability to predict which areas are most likely to be lost or gained.

Opportunities for Successful Implementation:

Key opportunities for successful implementation of this strategy are: 1) to develop a climate smart seed mix, e.g., change the proportion of cool:warm season species in seed mixes or add warm season species into seed mixes, especially at lower elevations; 2) to review and amend the agency policies for native plant materials; 3) research and monitor innovative practices, e.g., test which seeds would do better; and 4) to implement adaptive grazing management.

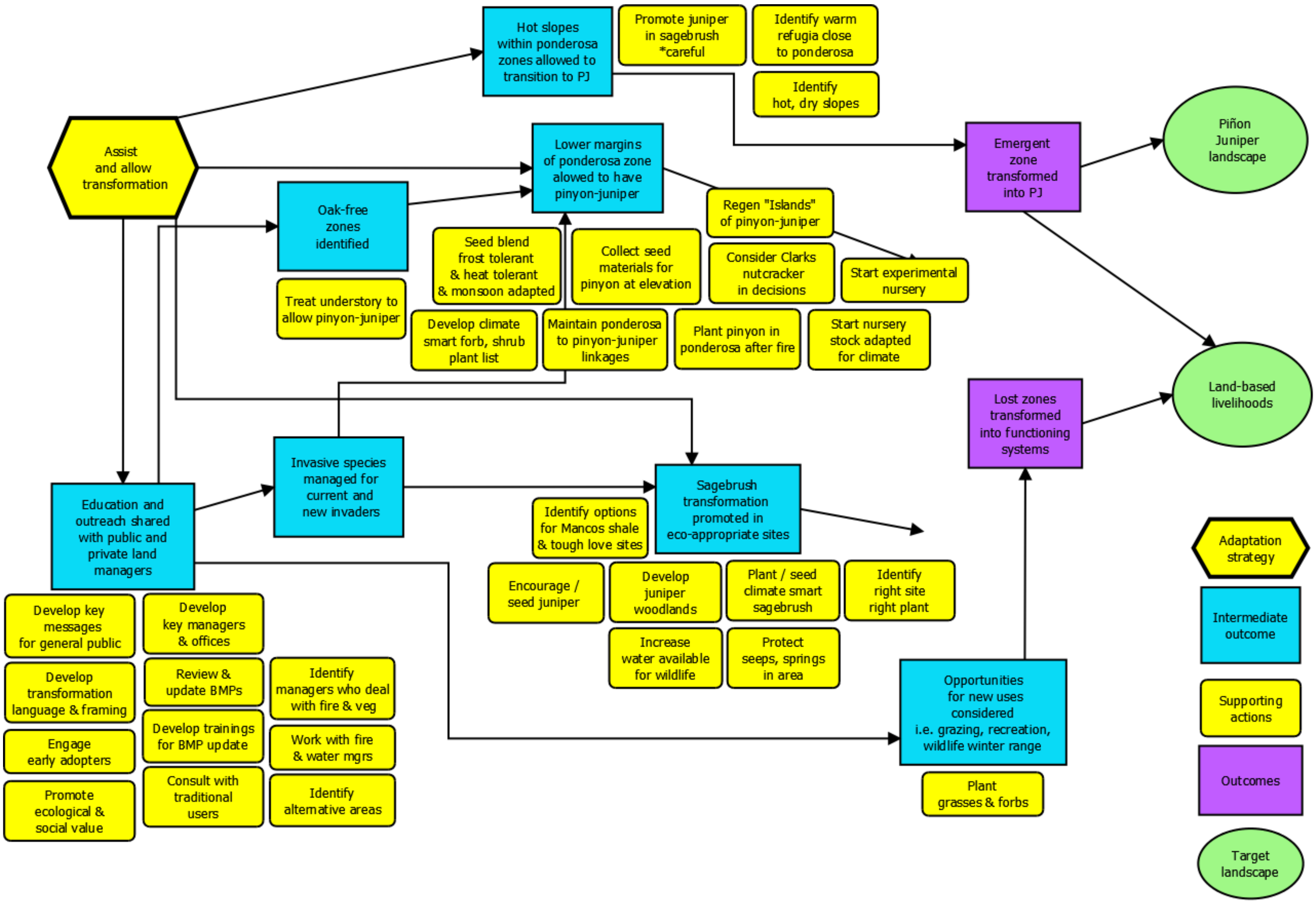

Figure 5. Results chain describing outcomes and actions for the assist and allow transformation strategy.

NEXT STEPS

1. Develop a social vulnerability assessment for the San Juan Basin, incorporating exposure, sensitivity, and adaptive capacity, thus identifying which social sectors are most vulnerable.
2. Share project results and seek feedback from upper level managers of USFS, BLM, NRCS, NPS, etc.
3. Develop an outreach plan for the key strategies; initiate research and monitoring; and design workshops.
4. Clear up ecological misunderstandings associated with natural distribution of pinyon pine and juniper.
5. Further develop the strategies, particularly the assist and allow transformation strategy, to help clarify the desired outcomes and audience.
6. Develop a clearinghouse for sharing maps, GIS data, charts, graphs, bio-climate models, and other products that are accessible to managers, participants and stakeholders.
7. Initiate an on-the-ground adaptation strategy with partners, e.g., controlling cheatgrass invasion.
8. Apply and refine the social-ecological framework to additional conservation targets and in other regions.
9. Publish a concept paper.
10. Develop diverse and creative communication packets that can be utilized by various audiences.
11. Develop a streamlined template of the framework that can be applied to other conservation projects across the state and to other states.

CONCLUSIONS AND LESSONS LEARNED

The planning framework used for this project consisted of assessing ecological vulnerabilities; selecting multiple social-ecological landscapes; developing climate scenarios; developing narrative scenarios and ecological response models; conducting social science interviews/focus groups, developing social-ecological response models; identifying impacts and interventions, and developing adaptation strategies. The framework was applied using a stakeholder-driven process with natural resource managers and researchers to develop robust climate adaptation strategies for the pinyon-juniper landscape in the San Juan Basin.

The project team worked with the San Juan Climate Initative and other stakeholders to apply the planning framework to two targeted landscapes (pinyon-juniper woodlands and seeps, springs and wetlands) in the San Juan Basin in Colorado. At the same time, another group of stakeholders focused on spruce-fir forests and sagebrush in the Gunnison Basin (described in a separate report). The two groups ended up with similar themes of adaptation strategies: conserve climate refugia, proactively treat for resilience, and assist and allow transformation within emergent and threatened zones.

Important next steps include developing an adaptation strategy plan, implementing actions, and designing a monitoring plan to detect trends, and evaluate the efficacy of actions. A social vulnerability assessment would further connect the human component to the ecological component. This framework could be applied in other landscapes and inform on-the-ground work to prepare for change.

Lessons Learned

Climate Scenarios and Bio-Climatic Models

Developing impacts and interventions for one climate scenario (Feast and Famine) first and then evaluating how well those strategies addressed the other two scenarios helped to streamline the process. A number of workshop participants commented about the utility of the bio-climatic models to help visualize geographically opportunities for implementing strategies. One participant suggested the need for more consideration of extreme events in all scenarios, interventions and strategies.

Situation Analysis and Chain of Consequences Methods

Workshop participants suggested using Situation Analysis first to brainstorm and explore a broad range of impacts followed by the Chain of Consequences to drill down into more specific consequences and interventions. Some participants found it challenging to follow the use of sticky notes for developing the Situation Analysis and suggesting using sideboards to help guide the process and outcomes. It is important to allow enough time to develop comprehensive chains and interventions, potentially up to one-half day per impact. Additional preparation may improve efficiency given the time constraints, e.g., having a "pre-loaded" list of primary consequences from which to react to and build from may have saved time at the workshop.

Opportunity to compare results developed by different groups

Different participant groups produced different results at the 2015 workshop using the two different methods, Situation Analyses and Chain of Consequences. While the primary consequences were similar among groups, the choice of which chains to further develop, chain length, and the focus on ecological versus socioeconomic consequences differed among groups. Some results clearly reflected the composition of the group (e.g., groups with more social scientists explored more social and economic issues). Therefore, in order to have a balanced outcome that integrates social and ecological interests requires careful attention to recruiting participation from the full suite of stakeholders within a system of interest.

Social Science

The social science research can help ecologists, climate scientists, and stakeholders understand how decision makers view and currently address climate change, which leads to more robust strategies. The use of narrative scenarios in a participatory workshop allowed natural resource manager and permittes to discuss climate impacts and their responses to impacts in a facilitated group setting. Coupling the results of the social science interviews and participatory narrative scenarios workshops provided an initial set of responses and challenges that decision makers are faced with. One example of an important result is that the mangers view a feast and famine scenario as extremely challenging even though the ecological impacts were not as severe as the hot and dry scenario. The social scientist were not able to attend all of the additional workshops that were held, e.g. developing impacts and interventions workshop and building strategies workshop.

In an ideal world, social scientist would have been at all of the workshops, thus ensuring a fully integrated social-ecological project.

Results Chains

Workshop participants noted that walking through the Results Chains step by step, discussing gaps or redundancies, was useful in developing the strategies and stimulating discussion and refinement. The Results Chains provided a structure to develop actions, but due to time constraints we were not able to develop more detailed and measurable action items. Having workshop participants present the results chains was informative and it was helpful to link them to the goals and objectives.

Workshops

The workshops provided an opportunity for thought-provoking discussion, interaction and learning for an interdisciplinary group of stakeholders, managers, and academics with different perspectives. The process of discussing goals and outcomes with state and regional stakeholders enabled participants to put their work into the larger perspective. Engaging participants to present results of breakout group work, goals/objectives or strategies helped with understanding and buy-in and stimulated good discussion. Participants noted the importance of providing all materials developed through this project for reference at each workshop. The workshops provided a wonderful opportunity for managers, tribal staff, scientists, and resource specialists to engage with others from different agencies, tribes, and districts. After the earlier workshops, several participants commented that it would have been useful to have more diverse user groups, e.g., non-governmental stakeholders. The team worked to broaden representation for later workshops.

Approach and Duration

This project applied multiple methods to identify impacts of climate change on the pinyon-juniper landscape and to develop social-ecological adaptation strategies, e.g., ecological response models, Chain of Consequences, Situation Analysis, social science, and Results Chains. This stakeholder-driven process took over three years to conclude. Application of different methods resulted in similar adaptation strategies- for instance, the basic strategies of protect refugia rose to the top for all of the landscape targets. Thus, in the future, to increase efficiency in developing adaptation strategies for other landscapes or ecosystems, teams may utilize only one or two methods to develop robust strategies. Developing the products over a shorter time period might help with ensuring consistent participation at workshops.

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APPENDICES

A. Glossary
B. Workshop participants for the pinyon-juniper landscape
C. Climate scenarios
D. Three narrative scenarios used in focus groups
E. Ecological response models
F. Social science interview and focus group reports
G. Social-ecological response models
H. Situation Analysis Results
I. Chain of Consequences Results
J. Impacts and interventions associated with three climate scenarios
K. Bio-Climatic Zones