Department of the Interior

NORTH CENTRAL CLIMATE ADAPTATION SCIENCE CENTER

UNIVERSITY CONSORTIUM

Department of the Interior North Central Climate (Adaptation) Science Center Final Report

Host account: G11AC90009

2011-2018

Colorado State University

The North Central Climate (Adaptation) Science Center Final Report: 2011- 2018

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Note: The name of the Center was changed to the North Central Climate Adaptation Science Center (NC CASC) in April 2018. We have chosen to not change the name throughout this document, as the name changed towards the very end of this award.

Preface

The final NC CSC University Consortium report hosted by Colorado State University covers the operational and research outcomes from October 21, 2010 through September 14, 2018. Our University Consortium and USGS leadership jointly coordinated and managed research, training, and outreach operations of the NC CSC enterprise. Colorado State University with the award, G11AC90009, was designated as the lead management entity of the University Consortium. The University Consortium was comprised of the University of Colorado, Colorado School of Mines, University of Nebraska-Lincoln, University of Wyoming, Montana State University, University of Montana, Kansas State University and Iowa State University. Under both of our federal directors, we operated as a joint enterprise. The USGS-side funded the directed and solicited research projects described within, but CSU administered all of the non-USGS grants through the host agreement.

As the lead management entity for grant G11AC90009, CSU managed the North Central University Consortium (NCUC), administered projects awarded to Consortium Universities or other partners, managed and implemented communications and reporting to the national office, worked as collaborators with any USGS-led research, outreach and training, managed budgets and coordinated Foundational Science Area research, hosted research coordination meetings, facilitated Native American and indigenous engagement, planned and executed the Open Science Conference, contributed to strategic planning, and allowed for the completion of ad hoc requests from collaborators and partners.

This report focuses on the research, training and outreach components of our enterprise leading to our various products, outcomes, and activities sponsored by our NC CSC efforts. A separate financial report will be submitted by CSU regarding expenditures and accounting of funds dispersed to CSU for the University Consortium Host agreement.

We are grateful to University partners - University of Colorado, Colorado School of Mines, University of Nebraska-Lincoln, University of Wyoming, Montana State University, University of Montana, Kansas State University, and Iowa State University - for their willingness to participate in this new endeavor by the United States Department of Interior and the United States Geological Survey; to the staff, faculty, and students at Colorado State University and across the consortium who lent their support and talents to ably implement the leadership and coordination of the University Consortium; and to our USGS and other federal partners who worked diligently with the University Consortium to provide the best information and tools to our natural resource managers across our region.

Introduction

The North Central Climate Science Center (NC CSC), now called the North Central Climate Adaptation Science Center (NC CASC), was established in 2011 in response to the U.S. Department of the Interior's (DOI) interest in providing the best available Earth science information to federal resource managers, state wildlife agencies, and tribal environmental professionals in the North Central U.S. The NC CSC is one of eight such regional centers. To meet this need, the NC CSC has established collaborations across DOI agencies and with nine university partners throughout the region.

The NC CSC's region has a large north-south extent, stretching from Montana and North Dakota south to Colorado and Kansas (Figure 1). This diverse landscape includes a variety of ecosystems and wildlife affected by climate change, ranging from the alpine ecosystems of the Rocky Mountains to the grasslands of the Great Plains. Across this vast region, resource managers and local communities are faced with a variety of climatic impacts associated with changing seasonality of precipitation; warming trends affecting migration and seasonality of species and communities; and impacts on primary production, hydrological cycles, and biotic responses. Although the people across the region have adapted to past climate challenges, the magnitude of expected changes and impacts will exceed those of previous experience.

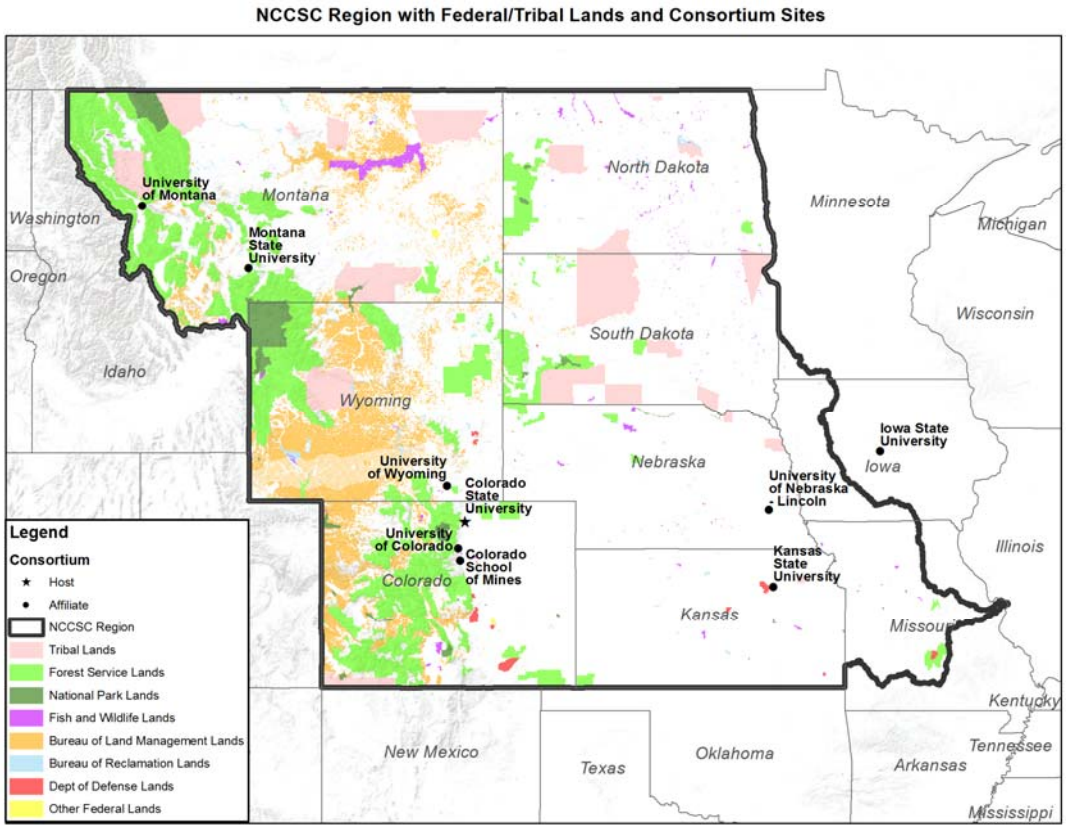


Figure 1: This map shows the geographic extent of the North Central Climate Science Center (NC CSC) domain. Federal and Tribal lands are shown and constitute 34% of the total area and represent the primary stakeholder lands in the region. The Climate Science Center is a collaboration between the Department of Interior and the North Central University Consortium (NCUC), whose members are shown here.

Driven by stakeholder needs, the NC CSC developed climate responsive management and adaptation strategies to address these impacts. To ensure relevance to management action, these strategies incorporate a social-ecological system perspective that looks across jurisdictions and scientific

disciplines in order to meet these challenges and to identify opportunities under these changing conditions. Overall, the NC CSC analyzed the climate drivers in the region; the impacts of those drivers on fish, wildlife, and habitats; and the adaptation management actions that contribute to healthy ecosystems and ecosystem services throughout the region, and thus provided actionable science-based information to managers to inform their decision-making in the context of climate changes.

Vision

The DOI mandate to establish the CSCs states that "…the United States Geological Survey (USGS) has been developing regional science centers to provide climate change impact data and analysis geared to the needs of fish and wildlife managers as they develop adaptation strategies in response to climate change" and that these regional CSCs should "…broaden their mandate to encompass other climate-change-related impacts on Departmental resources… (to) synthesize and integrate climate change impact data and develop tools that the Department's managers and partners can use when managing the Department's land, water, fish and wildlife, and cultural heritage resources." The vision of the NC CSC extends this national DOI scientific vision to the specific regional needs of the North Central domain.

Climate in the NC CSC is strongly connected to topography of the Rocky Mountains and vegetation and soil properties of the Great Plains. Surface hydrology, a key driver of ecological diversity and wildlife abundance, is determined by the interaction of these landforms and weather. For example, about two-thirds of spring and summer rainfall originates from a land source, primarily from within the NC CSC region but also from land residing north, south, or southwest of the region (Brubaker and others, 2001); whereas, the bulk of mountain snowpack has an oceanic source. The path of weather systems as they move from west to east and their storm track's predominant north-south position determines the pattern of dry and wet sub-regions within the NC CSC domain.

Goal and Objectives

The goal of the NC CSC is to provide the best available climate science and tools to inform natural resource management within the North Central domain. This effort is being done in conjunction with the National Climate Change and Wildlife Science Center (NCCWSC) and is coordinated with the activities of the other regional climate science centers.

To achieve this goal, the NC CSC defined a set of objectives to guide the operational aspects of the Center. These objectives are:

- Coordinate and guide the compilation and application of existing climate information, focusing on the regional accuracy and uncertainty of this information and considering historic data and future projections
- Understand climate impacts and consequences of climate change on ecosystem goods and services and the implications for key regional sectors; natural, cultural, and energy resources
- Evaluate vulnerability of major regional assets and sectors, synthesizing physical, ecological, and social perspectives that include assessment of adaptive capacity and consider human livelihood, health, and safety
- Develop and improve decision support tools in collaboration with stakeholders to evaluate (alternate) management and response strategies to address climate change issues
- Provide an engagement platform to enhance information exchange between resource managers and researchers to improve usability of the research information needed for managing resources under climate change

These objectives provide a framework to produce actionable science and to enhance continued engagement between the resource management and research communities in the region. These objectives are meant to be integrative, cross-disciplinary, synthetic across scales and sectors throughout

the region, and facilitate iterative engagement with resource managers, decision makers, and researchers. To meet these objectives, the NC CSC designed a five-year science agenda (2012-2017) toward science delivery through the **R**esource for **V**ulnerability **A**ssessment, **A**daptation and **M**itigation **P**rojects (ReVAMP) platform described below (Morisette 2012; DOI USGS Open-File Report 2012-1265).

Guiding Principles

The guiding principles of the NC CSC broadly describe how the center conducts its business. These principles build on a National Research Council Report (2009). Within the DOI and regional context, the three main constituent groups for the center include the North Central University Consortium (NCUC), USGS centers in the region, and the NC CSC's Joint Stakeholder Committee (JSC). Based on the NRC report and the collective experience of these constituent groups, the NC CSC developed the following guiding principles (based on National Research Council, 2009):

- Principle 1: Build on existing documents, assessments, indicators, and frameworks (in other words, don't "reinvent the wheel").
- Principle 2: Understand and demonstrate to resource managers the implications of a climate where means and moments of the temperature and precipitation distribution vary over time (that is, help managers understand the implications of a non-stationary climate).
- Principle 3: Start with the end user in mind and prioritize research that is useful and usable.
- Principle 4: Consider the center as a coordinated research team (and not a funding center) and focus on the unique capabilities of both the team and a coordinated regional initiative.
- Principle 5: Respect the unique demands and constraints on the stakeholders and research partners (which represent a wide array of Federal, State, Native American, and university employees where each institution has its own set of constraints and incentives).

In addition to the NRC report, the Advisory Committee on Climate Change and Natural Resource Science (ACCCNRS report 2015) recommended that the regional CSCs develop research that would lead to actionable science. The ACCCNRS report defines actionable science as research that "provides data, analyses, projections, or tools that can support decisions regarding the management of the risks and impacts of climate change. It is ideally co-produced by scientists and decision-makers and creates rigorous and accessible products to meet the needs of stakeholders." The report goes on to suggest that co-production of research would be conducive to producing actionable science. Co-production incorporates aspects of engagement, research development, and problem solving. The NC CSC made significant efforts to incorporate these aspects of co-production, leading to more effective delivery of actionable science to its natural and cultural resource management and decision making communities in the region.

Building the NC CSC as a Resource for Vulnerability Assessment, Adaptation, and Mitigation Projects

Stakeholders expressed a desire to have a resource that can help interpret and untangle the ever-increasing array of climate information. They asked the NC CSC to focus on management relevance and ensure that resource managers have access to products and can use them. Although peer-reviewed publications are important, managers have to be able to find and use information/tools (sometimes more quickly than waiting for a journal publication). These and other comments and observations have established a need for technical assistance in applying climate science to the management process, including vulnerability assessments, adaptation, and mitigation.

As a result, in 2012, the NC CSC developed its science strategy to meet these needs by positioning itself as a "Resource for (climate-informed) Vulnerability assessment, Adaptation, and Mitigation Projects" (ReVAMP; Morisette 2012). ReVAMP became a centralizing theme to coordinate research done through the NC CSC and provided a mechanism by which the NC CSC served stakeholder needs. The strength of the ReVAMP concept was bringing state-of-the-science climate information into models of ecological impacts and management responses in a collaborative, co-production of knowledge with scientists and managers. Through these activities, the Center developed integrated information relevant to natural resource managers.

The ReVAMP was philosophically rooted in the objectives and guiding principles listed above, and over the past seven years it became a tangible and operational reality. The specific components of this resource are:

1. A consistent and ongoing investment in three foundational science areas (FSAs)
2. The solicitation and funding of management-relevant, decision-focused projects
3. Science delivery through a collaborative workspace, training, capacity building, communications, and ad hoc support

Foundational Science Areas of the ReVAMP

The introduction of three FSAs offered an integrated approach to informing resource managers and researchers in the North Central region (Figure 2):

- ***Climate Drivers:*** Understanding and quantifying drivers of regional climate changes
- ***Ecological Impacts:*** Assessing impacts of climate change on the natural resources of the region and the resulting vulnerability of social-ecological system components
- ***Adaptation:*** Characterizing adaptive capacity and mitigation options for communities and natural resources

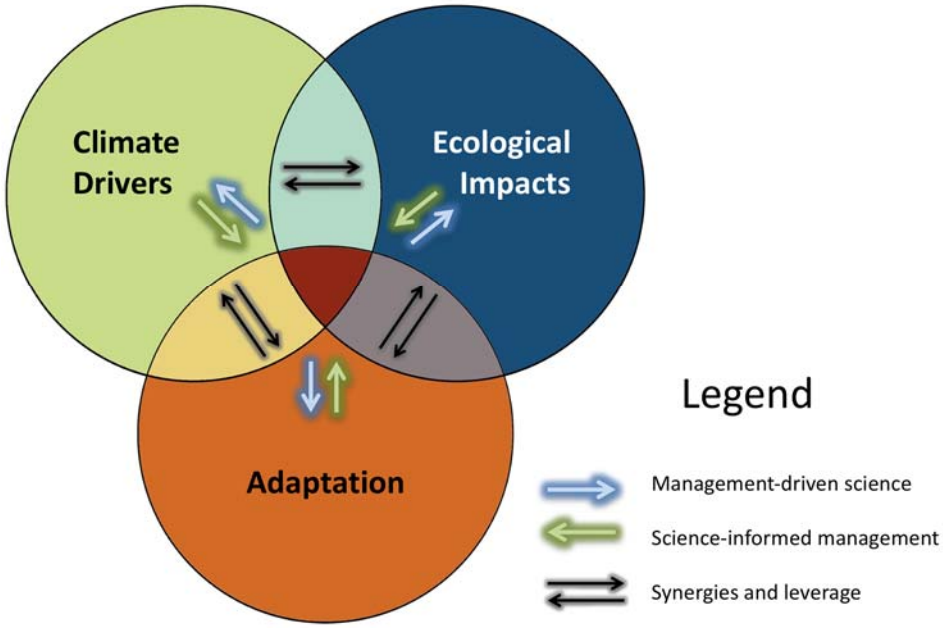


Figure 2: The three synergistic NC CSC foundational science areas (FSAs) include climate drivers, ecological impacts, and adaptation

It is important to note that the FSAs both inform management actions and are informed by management needs, represented by the green and blue arrows, respectively, in Figure 2. Also, the NC CSC looked for opportunities for synergies and leverage between the FSAs, represented by the black arrows. Key activities and products/deliverables for the FSAs can be found in Table 1.

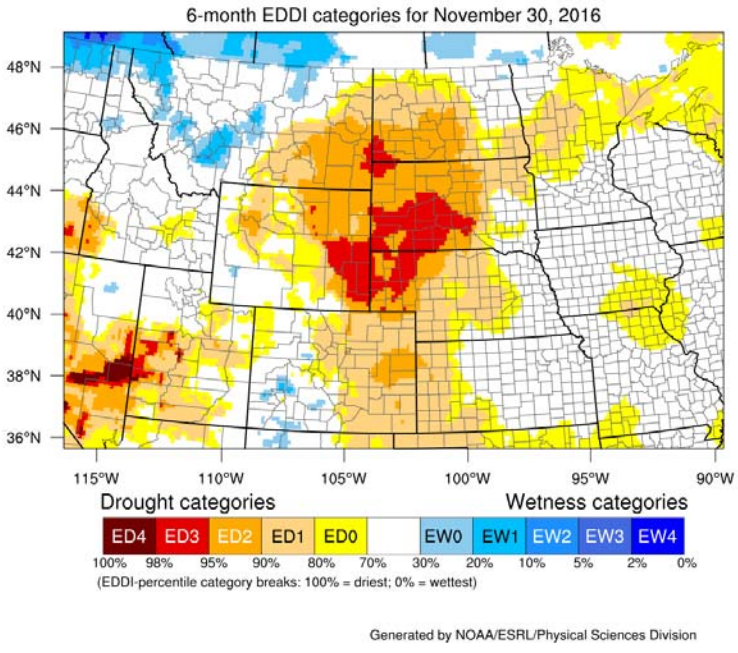
Climate Drivers: Understanding and Quantifying Drivers of Regional Climate Change

Climate-driver research for the NC CSC was directed toward clarifying and quantifying the trajectory of change in past, present, and future climate drivers within the NC CSC domain. Considerations for this research area included, but are not limited to, projected trends in temperature, precipitation, extreme weather events, derived climate variables, and resulting hydrology and water balance across the west to east moisture gradient. An important part of this foundational research area was quantifying the non-stationary nature of climate drivers for the region and to consider ways to either reduce or deal with the uncertainty of precipitation projections.

Developing Real-Time Physical Climate Tools

Actionable climate science is a common thread among NC CSC projects, including those with a more social science focus, such as adaptation and capacity building. There are, however, a few projects that fall entirely under the NC CSC's Climate Drivers FSA, which include the development of climate tools and datasets. Once developed, this work can be utilized in a variety of applications and often serves as a basis for regional climate models and planning.

An example of the NC CSC's physical climate work is the Evaporative Demand Drought Index (EDDI), a tool co-developed by the NC CSC climate team and local partners, including the Western Water Assessment (WWA). EDDI is a real-time drought monitoring tool, meaning it updates daily using the latest atmospheric data. The tool serves as an indicator of both long-term drought and "flash" drought, which occurs on the scale of a few weeks. The tool's short-term indicators can be used by irrigators, for example, to track water needs on a day-to-day basis. Long-term indicators, like the 6-month category, can be used for predictions like the risk of wildfire. EDDI is available on the WWA Climate Dashboard page at wwa.colorado.edu/climate/dashboard2.html.



Ecological Impacts and Vulnerabilities: Connecting Climate Drivers to Management Targets

Whereas climate drivers are a fundamental research component for the CSCs, for most management issues, climate is often not the primary concern. For example, land managers are more concerned about animal populations or ecosystem services than they are about changes or trends in temperature or precipitation. Yet climate drivers affect the conservation targets of concern. The NC CSC research efforts in the Ecological Impacts FSA explored how climate drivers relate to ecological impacts of interest to land managers. This FSA has leveraged ongoing and active research activities in the region and engaged research expertise in ecological response models where translational climate analysis can be incorporated to advance this work.

Surrogate Species as an Indicator of Wetland Health

Increasing temperatures threaten to dry millions of wetlands in the North Central U.S. and southern Canada in the Prairie Potholes Region, a critical habitat for nearly 120 species of wetland-dependent birds. A project led in part by Susan Skagen (USGS) and Barry Noon (CSU) evaluated the vulnerability of these birds in terms of exposure, sensitivity, and species-specific adaptive capacity. This included projecting future densities of wetlands inundated with water, projecting the range loss for nearly 30 species of breeding wetland birds, assessing sources of uncertainty in the modeling process, and evaluating the resilience of migrating shorebirds to wetland drying.

A goal of the study was to evaluate a "surrogate species" approach to conservation management. The team strove to determine whether the currently-used model group of waterfowl – five species of ducks, including the Mallard and Northern Pintail – also addressed the needs of the entire range of wetland-dependent birds, or whether a different species or group of species would serve as a better surrogate.

Long-billed dowitchers in wetlands of the Great Plains
Photo by Brady Neiles

Adaptation: Characterizing Adaptive Capacity of Stakeholder Communities and Informing Management Options

Connecting to decision makers is one of the main operating principles for the center and is integral to its mission. This connection is not always obvious or automatic; it requires not only a strong research program but also a strong interface with the user community, a platform for two-way dialogue, and continuous evaluation of the process (National Academy, 2000). Understanding and evaluating the adaptive capacity of socioecological systems in the North Central region was an integral component in the development of climate change management strategies. The vulnerability of natural resources and human communities and the adaptive capacity of the socioecological system vary across the region due to local, State, Tribal, and regional accessibility to socioecological capital resource assets. The NC CSC worked toward understanding the availability and use of capital resource assets in the region and how they are, or can be, used for implementing adaptive management practices.

In addition to the research conducted by each FSA team, the teams act as consultants to the NC CSC on both the management focused projects and science delivery described below. The FSA teams also helped to ensure coordination of the resulting research results with the research and needs of other national and regional initiatives. Priority regional coordination opportunities included working with the National Oceanic and Atmospheric Organization (NOAA) Western Water Assessment (WWA), the USDA Northern Plains Climate Hub, and Landscape Conservation Cooperatives (LCCs). Priority national level coordination opportunities included working with NOAA's National Climate Projection and Prediction program, the National Climate Assessment (NCA; disseminating information from the 2013 NCA and helping prepare information for the 2017 NCA), and the National Center for Atmospheric Research (NCAR).

This collaboration and coordinated efforts across research elements improved efficiency, understanding, and utility for use in natural resource management decision making. Cross-project meetings (face-to-face and virtual) among the FSA teams, funded investigators, coordinated efforts, and management entities working with the NC CSC were held to co-produce research products and translational materials that are relevant, useful, and usable for natural resource management decisions. The FSA teams played a major role in the development of this integrated synthesis of research products aimed to meet natural resource management needs.

Supporting Tribal Drought Preparedness

With drought as one of the NC CSC's organizational themes, many of the adaptation and capacity-building projects conducted by the center have at least some drought component. One management-focused project in the Wind River Indian Reservation of Wyoming combined social science, physical science, and ecological impacts teams to work in cross-institutional partnerships to evaluate drought vulnerability and develop decision support tools for drought preparedness. The project, led in part by the NC CSC adaptation team, built on ongoing work to understand how federal agencies work with each other and with tribes to prepare for and respond to drought. Long-term goals included bringing lessons learned to other tribes and non-tribal entities.

Wind River, Wyoming
Photo by Zack Frank

Table 1: Key activities and products/deliverables* for the foundational science areas

FSA	Activities	Key products or deliverables
Climate Drivers Team Lead: Imtiaz Rangwala *University of Colorado Boulder*	Publications, expert opinion, and consultation focused on climate implications and scenarios for ecosystems/habitats of concern to NC CSC stakeholders	Engaged consulting at numerous workshops from the management-focused projects and ad hoc support
	World-class research on North Central regional climate models and regional accuracy of national or global climate modeling, with an understanding of how that research fits client-based and management decision activities	Rangwala et al. 2016; Dewes et al. 2017; Hobbins et al. 2017
	Contributions to the National Climate Assessment efforts	Rangwala and Barsugli contributors to report for NCA (Cayan et al. 2013)
	Climate information and products that are accessible and useable through ReVAMP as input to the other components of the framework	Consultation on EDDI, TopoWx, LERI Evaluation of MACA
Ecological Impacts Team Lead: Andrew Hanson *Montana State University*	Quantifying and mapping habitat integrity factors that influence the productivity and extent of key habitats across the domain	Garroutte et al. 2016; McClure et al. 2016; Adhikari and Hansen 2018
	Evaluating species-level sensitivity to climate drivers that may affect the species' success	Hansen and Phillips 2015; Hansen and Phillips 2018
	Initiating work to assess changes to ecosystem services that would alter management considerations of those resources	Hansen et al., eds. 2016
	Coordinating the ecological-response-modeling component of the ReVAMP, which provides the link between the state-of-the-science understanding of climate with resource management decision support tools.	Hansen et al., eds. 2016
Adaptation Team Leads: Dennis Ojima & Shannon McNeeley *Colorado State University*	Exploring how climate changes affect local-scale social-ecological systems, trigger threshold events, and create nonlinear interactions across an interwoven set of stressors and how these get reflected in local management decisions and practices	McNeeley et al. 2016; McNeeley et al. in prep.
	Developing more detailed information on management options and institutional resources and how these are utilized under various decision-making situations	McNeeley 2014; McNeeley et al. 2017
	Developing both qualitative and quantitative decision-support tools for the ReVAMP	Wind River Indian Reservation drought summaries (nccsc.colostate.edu/revamp/project/wind-river-drought-preparedness); CO BLM: Social Vulnerability Assessment

*See Appendix: NC CSC Funded Project Descriptions and Products

Management-Focused Solicited Research Projects

Early on the NC CSC incorporated aspects of the "Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment" (Glick et al. 2011) to guide the research and engagement strategies (Figure 3). Climate change vulnerability assessments help identify which species or systems are likely to be strongly affected by projected changes and help the NC CSC understand why these resources are likely to be vulnerable, including the interaction between climate shifts and existing stressors (Glick et al. 2011). In addition, the center has incorporated aspects of the social-ecological system perspective to better address decision making challenges in responding to changes managers are faced with in the region.

In four separate rounds of solicitation – in fiscal years 2012, 2013, 2015, and 2017 – the NC CSC competitively selected projects with a clear "articulation of the decision that is being considered and how it addresses important Department of Interior land, water, fish and wildlife, or cultural heritage resources in the region" and the inclusion of resource management decision makers as collaborators

Management-Focused Research:
Turning Scenario Planning into a Workable Action Plan for the Great Plains

It can be difficult for regional land managers to narrow down and select from the multitude of future climate scenarios, much less make decisions for future planning based on those predictions. Amy Symstad (USGS, Northern Prairie Wildlife Research Center) led a project team that took the guesswork out of scenario planning in the northern Great Plains by developing region-specific climate scenarios and leading workshops and outreach. Climate scenario training and models were presented in workshops that included federal agencies (e.g., NOAA, NPS, USFS, USFWS), state agencies (e.g., North Dakota State Historical Society), tribal partners (e.g., Mandan, Hidatsa and Arikara Nation), non-governmental organizations (e.g., The Nature Conservancy, Wildlife Conservation Society), and university scientists (e.g., South Dakota School of Mines and Technology and Colorado State University), and follow-up work was conducted that expanded the scope and reach by informing specific management strategies for the northern Great Plains.

Workshop participants developed a timeline of climate change and resource impacts over the next 35 years for one of the climate scenarios across a diversity of resources.

and/or investigators (Figures 4 & 5). These solicited projects help connect the FSA work with critical resource management needs and helped to define the specific capacity that was built into the ReVAMP framework (Table 2).

It is helpful to consider these solicitations in light of Figures 2 and 3 and how they relate to each other. The solicited projects were required to articulate a management framework (the framework in Figure 3 is one example, but others were allowed, such as, Cross et al. IPCC 2007, etc.) wherein the NC CSC provided support to that activity through ReVAMP. The NC CSC selected projects that contained a strong management-focus and significant climate, impacts, and adaptation components represented by the three-way intersection shown in Figure 2.

Figure 3: Framework for developing climate change adaptation strategies (modified from Glick and others, 2011) with the additional demarcation showing the NC CSC interpretation of LCCs' and other stakeholders', and CSCs' relationship to that framework. Represented by the green ring on Figure 3, the NC CSC relies on stakeholders to provide expertise in steps 1 and 4. Represented by the blue ring, the NC CSC efforts leverage the FSAs and decision-focused project to conduct steps 2: vulnerability assessment and 3: identification of management options. The rings intentionally overlap; whereas is it helpful to understand that the NC CSC can provide more assistance with steps 2 and 3, it must be done in close communication and interaction with stakeholders iteratively with steps 1 and 4 of the framework.

NC CSC Project Solicitation Process

Solicitations have followed a three-step process—formulation, review, and implementation—each of which involves the (joint) stakeholder advisory committee. The first step is the formulation of the solicitation. Considerations at this stage include total funding available for all selected projects, anticipated budget range and duration for a given project, and a description of the priority areas and criteria for the proposed projects. A draft of the solicitation is constructed by NC CSC USGS staff based on the overall strategy laid out in the five-year plan, available budgets, and priorities noted through previous stakeholder engagement. This draft is then circulated to the (joint) stakeholder committee for comments and edits. Once these have been incorporated into the solicitation, it is passed on to the national office for final edits and consistency in timing of the release relative to other CSC and national solicitations.

The next step is the review of the solicitation. Solicitations are open through the NCCWSC Request for Proposal Manager (RFPManager). NCCWSC coordinates these so that all CSC solicitations are open at the same time for a given year. Each CSC and the national office notify the community of the solicitations through email, newsletters, social media, and websites. Proposals are submitted to the RFP manager, which requires certain logistical information, allows upload of the full proposal in PDF form, and provides templates for budgets and Data Management Plans. For its solicitations, the NC CSC has offered question and answer sessions shortly after the release (and well ahead of the proposal due date). Eligible Principle Investigators include members of the University Consortium or USGS employees, although subcontracts are open to other collaborators. Once submitted, the NC CSC has arranged a review panel to both independently score all proposals and have a phone/web-based review panel discussion. The NC CSC has utilized the Joint Stakeholder Committee (JSC) and Landscape Conservation Cooperative (LCC) representatives for members of its review panels. After scores have been submitted, the review panel has met, and the NC CSC considers its own program balance in both topic and spatial representation, the NC CSC recommends to NCCSWSC a subset of proposals for funding. NCCWSC then works with leadership within USGS and DOI to select the final projects for funding.

Once projects are selected, NC CSC staff notifies the recipients and works with each proposal team to implement the projects. In addition to the proposed work, the NC CSC requests that at least one representative attend monthly NC CSC “check-in” webinars. Annual and final reports are also required.

Management-Focused Research: Adaptation Planning in Southwestern Colorado

Adaptation planning and management must often be tailored to meet specific agency and stakeholder needs. The NC CSC's cross-agency social-ecological climate resilience project in southwestern Colorado took these site-specific needs into account. A joint team of resource managers, NGO partners, and university and USGS researchers conducted ecological vulnerability assessments, institutional analyses, interviews, and other groundwork that led to adaptation strategies built specifically for the communities and species of southwestern Colorado. For instance, re-establishment of water retention areas to support water supply for the Gunnison sage-grouse has enabled the maintenance of populations in the area.

In addition to that region-specific work, the team also reported on lessons learned and created a set of tools and guidelines that can be applied more broadly to other landscapes. The inclusion of a strong social science component both informed the direction of the work and provided key insights into adaptive capacity at an institutional level, ensuring the guidance will apply to other institutions and constituents.

The Gunnison sage-grouse is one species that benefits from adaptation management efforts in southwestern Colorado. Photo courtesy of USDA

Table 2: Summary of management-focused projects (see appendices for descriptions). The table lists the year the project was initiated, the duration of the project, principal investigator, affiliation of the principal investigator, the management issue being addressed, the major connection with one or more FSAs, and key publications coming from the project (continues to pp. 14 and 15).

Solicitation	Duration	Title	PI	PI Affiliation	Management needs	Unique FSA considerations	Key Results
2012	1 year	The value of climate information for supporting management decisions within the Plains and Prairie Potholes LCC	Max Post van der Burg	USGS Northern Prairie Wildlife Research Center	Climate implications for invasive species with the Plains and Prairie Pothole LCC	Adaptation FSA: economic analysis on the value of information	Post van der Burg et al. 2016
2012	1 year	Projecting climate change effects on cottonwood and willow seed dispersal phenology, flood timing, and seedling recruitment in western riparian forests	Patrick Shafroth	USGS Fort Collins Science Center	Riparian management with FWS	Impacts FSA: integration of three ecological models, hydrological, snow melt, and seed recruitment	Ray 2016 in prep.
2012	1 year	Integrating climate and biological data into land management decision models to assess species and habitat vulnerability: A collaboration for Greater Sage-Grouse and their habitats	Richard S. Sojda	USGS Northern Rocky Mountain Science Center	Understanding sage brush and sage grouse decisions faced by the USFW and BLM managers	Adaptation FSA: climate-informed adaptive management approach at pilot site	Ray 2016 in prep.
2012	1 year	Projecting future effects of land management, natural disturbance, and CO_2 on woody encroachment in the northern Great Plains in a changing climate	Amy Symstad	USGS Northern Prairie Wildlife Research Center	Management of woody encroachment at Wind Cave National Park	Climate and Impacts FSA: integrating downscaled climate projects with dynamic vegetation model (MC1)	Symstad and Leis 2017; King et al. 2015
2013	3 years	Informing implementation of the Greater Yellowstone Coordinating Committee's (GYCC) Whitebark Pine (WBP) Strategy based on climate sciences, ecological forecasting, and valuation of WBP-related ecosystem services	Andrew Hansen	Montana State University	Climate-informed management of White Bark Pine communities via the White Bark Pine subcommittee of the Greater Yellowstone Coordinating Committee	Climate FSA: Paleodata applications Impacts FSA: climate niche modeling for multiple tree species throughout the Greater Yellowstone Area Adaptation FSA: survey of public support for WBP	See Appendix 1, 9 publications. Hansen, Monahan, Theobald and Olliff, eds. 2016. Climate Change in Wildlands.
2013	3 years	Surrogate species for wetland-dependent birds in the prairie pothole region: selection, evaluation, and management application in the face of climate change	Susan Skagen and Barry Noon	USGS Fort Collins Science Center and Colorado State University	Implications of using a surrogate species approach to management water fowl in the context of climate change	Climate and Impacts FSA: focus on the hydrological implications of climate change in the Plains and Prairie Pothole region	See Appendix 1 – four publications

Solicitation	Duration	Title	PI	PI Affiliation	Management needs	Unique FSA considerations	Key Results
2013	4 years	Natural Resource Management Decision-Making under Climate Uncertainty: Building Social-Ecological Resilience in Southwestern Colorado	Nina Burkardt	USGS Fort Collins Science Center	Holistic approach to management of federal and private lands at the landscape scale	Climate FSA: Methods for providing climate scenarios to wide range of stakeholder Adaptation FSA: significant attention on private lands, non-government organizations, and livelihoods, in the context of public land management	Six reports from multiple community engagement workshops. Forthcoming NCTC Climate Smart Conservation Training
2015	2 years	Understanding dynamics of land use switching with satellite and field level data in context of climate variability	David A. Hennessy	Iowa State University	Better target the use of public and private funds allocated toward incentivizing grassland preservation on private lands in the Dakotas	All three FSAs: integrating climate projections with existing agro-economic models	Wang et al. 2016, SDSU Extension article
2015	2 years	Informing adaptation strategies for maintaining landscape connectivity for Northern Rockies wildlife in the face of climate change	Steven Hostetler	USGS	Develop climate-smart strategies to help stakeholders manage public and private lands in ways that allow wildlife to continue to move in response to changing conditions	Impacts FSA: focus on connectivity and wildlife corridors for multiple species under multiple climate scenarios	Report on partners' climate adaptation goals, strategies, and actions; report on sensitivity scores and associated sensitivity factors for 16 focal species
2015	3 years	The Wind River Indian Reservation's Vulnerability to the Impacts of Drought and the Development of Decision Tools to Support Drought Preparedness	Cody Knutson and Shannon McNeeley	Iowa State University and Colorado State University	Developing decision tools to support drought preparedness at the Wind River Indian Reservation	Adaptation FSA: co-production with Eastern Shoshone and Northern Arapaho tribes, multiple federal agencies and university researchers of location-specific drought preparedness tools	Wind River seasonal drought summaries, March 2015-present

Solicitation	Duration	Title	PI	PI Affiliation	Management needs	Unique FSA considerations	Key Results
2015	2 years	Scaling climate change adaptation in the northern Great Plains through regional climate summaries and local qualitative-quantitative scenario planning workshops	Amy Symstad	USGS Northern Prairie Wildlife Research Center	Enhancing the National Park Service scenario planning activities	All three FSAs: integrating climate projections with simulation ecological modeling that incorporated management options discerned from scenario planning workshops	Two Natural Resource Reports NPS/NRSS/NRR
2015	3 years	Forecasting changes in sagebrush distribution and abundance under climate change: integration of spatial, temporal, and mechanistic models	Benjamin Poulter	Montana State University	Provide increased confidence in projections of range-wide mapping of sage grouse habitat change	Impacts FSA: integration of mechanistic and correlative ecological response models	Dynamic Global Vegetation Modeling workshop; Sagebrush working group meeting
2017	2 years	Technical Assistance and Capacity-building for the NPS: Actionable Science for Badlands National Park and Devils Tower National Monument and a New Model for Incorporating Climate Science into Resource Stewardship Strategies	Amy Symstad	USGS Northern Prairie Wildlife Research Center	Enhancing the National Park Service Resource Stewardship Strategies activities	All three FSAs: integrating climate projections with simulation ecological modeling that incorporated management options discerned from workshops	Badlands NP Resource Brief; Devil's Tower National Monument RSS and establishing process for including climate into RSSs (work on-going)
2017	1 year	Enabling Climate-Informed Planning and Decisions about Species of Conservation Concern in the North Central Region	Molly Cross	Wildlife Conservation Society	Identify climate-related scientific information needs that will support the management of key species and help avoid species declines	Climate FSA: climate scenarios	Identification of high priority species for conservation in region (work on-going)
2017	1 year	Building Social and Ecological Resilience to Climate Change in Southwestern Colorado: Phase 2	Nina Burkardt	USGS Fort Collins Science Center	Identification of actions that can support resilience and climate adaptation	Climate FSA: climate scenarios Adaptation FSA: resilience and adaptation in public land management	Outreach materials to contribute to development of specific actions to respond to change (work on-going)
2017	1 year	Ecology and management of Pinyon-Juniper woodlands: state of the science	John Bradford	USGS Southwest Biological Science Center	Evaluating possible management strategies for pinyon-juniper systems	Impacts FSA: Follow up on early sagebrush impacts work	Synthesis of literature on structure, function and management of pinyon-juniper systems

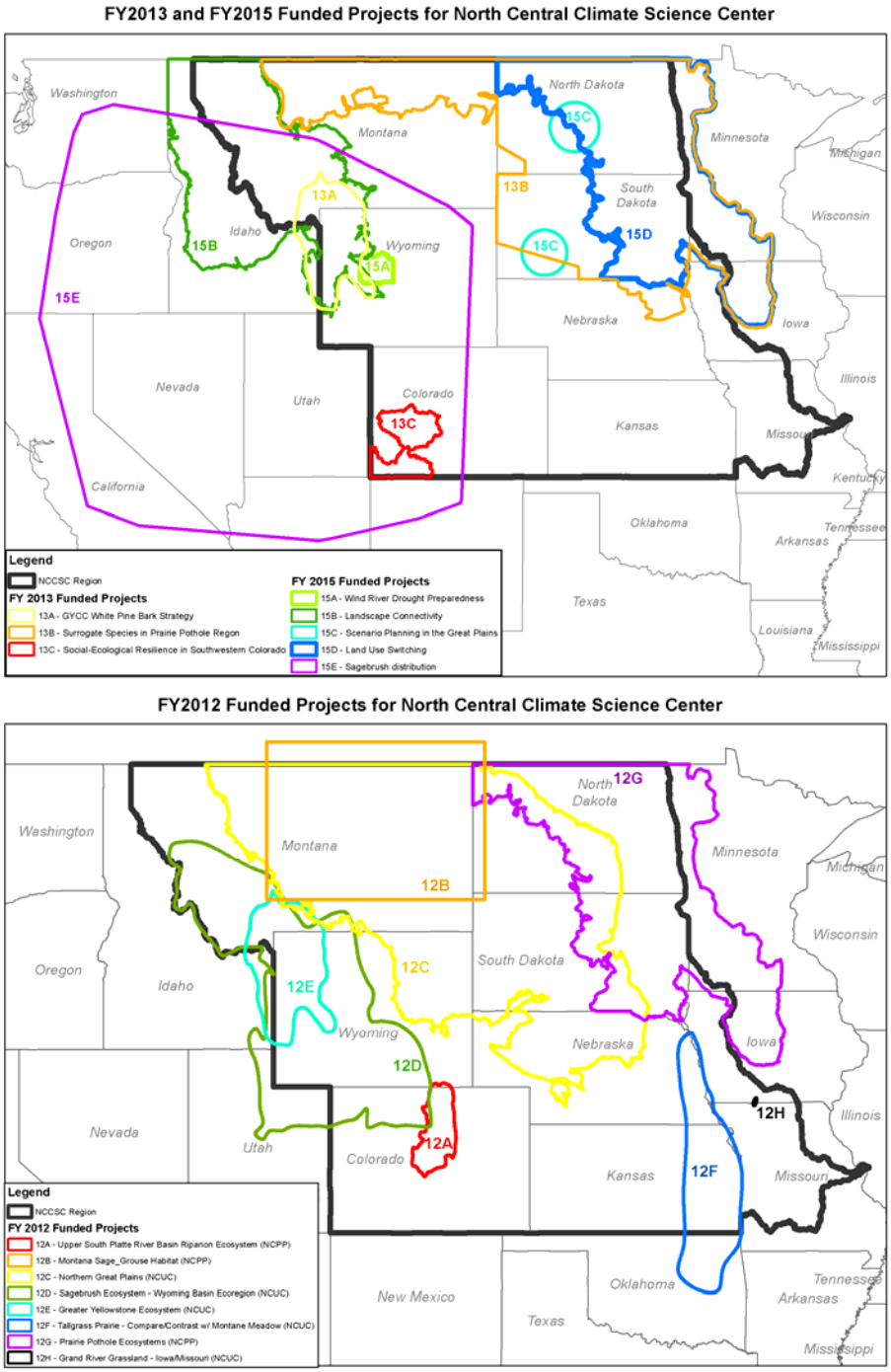


Figure 4: Maps of the study areas for management-focused solicited projects (FY12, 13 and 15).

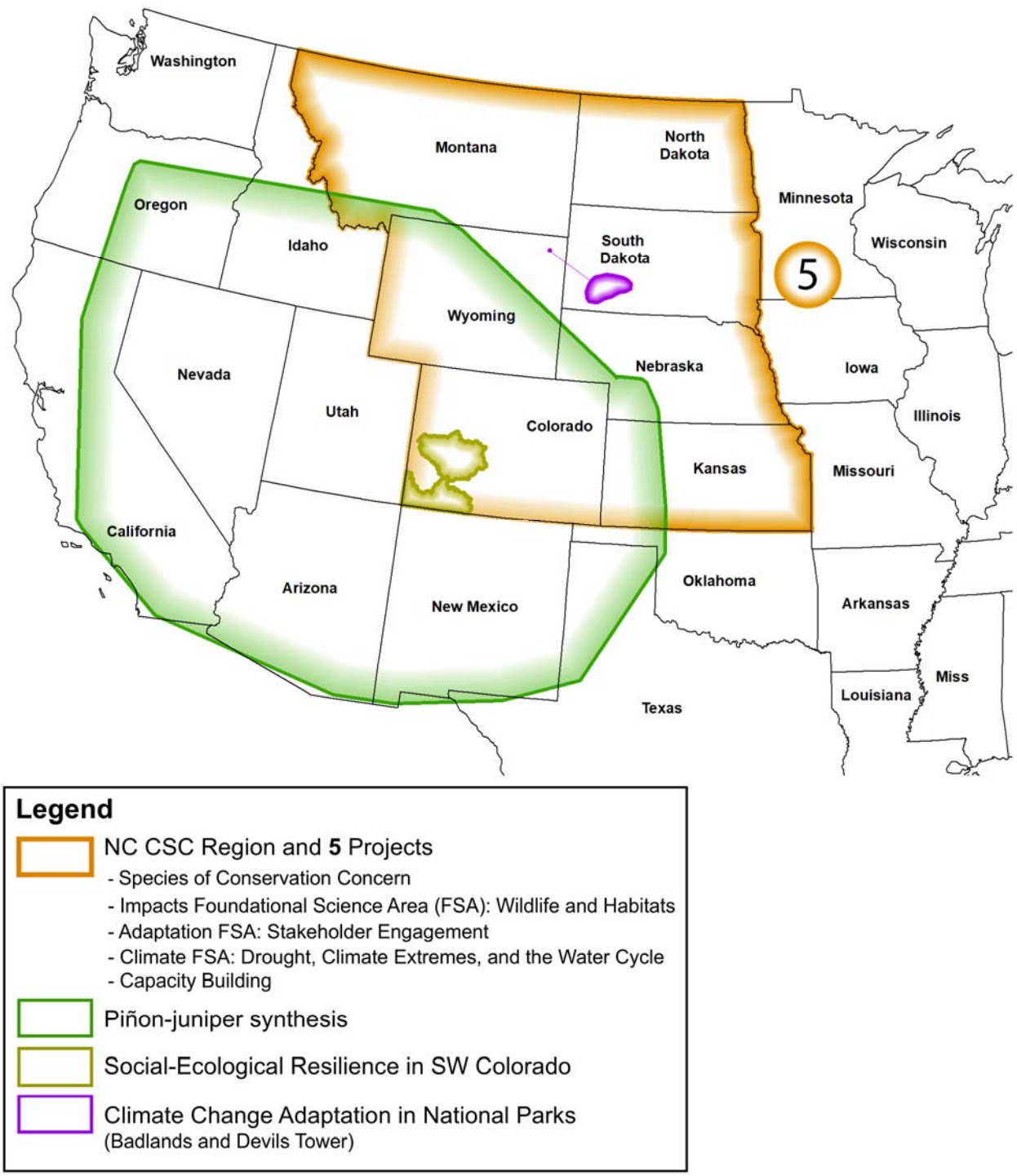


Figure 5: Maps of the study areas for management-focused solicited projects and Foundational Science Areas (FY17).

Science Delivery

As ReVAMP has been used to develop the three FSA themes and connect that science with management-focused projects, the NC CSC engages in science delivery to more fully realize the benefit of the work done by the center.

Utilizing the USGS Resource for Advanced Modeling (RAM) as a collaborative workspace

The NC CSC brought computing tools, climate data, and management needs together to address complex situations and help stakeholders explore possible future scenarios (Miller and Morisette 2014). Technical components are vital to implementing this vision via downscaling of global scenarios of climate futures and regionally-informed climate projections, ecological response models, and assessing social-ecological vulnerabilities and adaptation planning. The NC CSC has found that collaborative workshops and face-to-face meetings are important when bringing multiple stakeholders and interdisciplinary teams together to address these non-trivial issues.

To facilitate such meetings, the NC CSC has utilized the USGS Resource for Advanced Modeling (RAM – www.fort.usgs.gov/sites/default/files/RAM/index.html, Figure 6), which provides an opportunity to collaboratively address the inherently complex integration of climate data into ecological modeling in a way that directly supports resource management decision making in a changing climate. The NC CSC has worked closely with the USGS Fort Collins Science Center that hosts the RAM facilities. Research (Morisette et al., 2017) used the NC CSC's work in the RAM as a case study to describe the importance of the mechanisms for the co-production of knowledge. While calls for co-production and bridging different kinds of knowledge are widespread (e.g., NRC 2009), detailed understanding of the mechanisms in co-production of knowledge is less available. NC CSC's use of the RAM over the past five years has increased the center's understanding of such mechanisms and has been used to promote co-production of knowledge. The RAM was decommissioned in 2017.

Figure 6: The Resource for Advanced Modeling (RAM) "VisWall" is a bank of 24 wall-mounted monitors in a 6x4 array that can be used for displaying large or numerous GIS datasets, photos, or other data products. The VisWall is supported by a mini-cluster of over 100 processors to promote modeling efficiency. The image here demonstrates three models of cheatgrass distribution in the western U.S.

Capacity Building

In addition to supporting funded projects selected through its solicitation process or the directed funds going to the FSAs, the NC CSC also targeted funds to support capacity-building work to help the NC CSC achieve its goal. These projects support work that builds capacity among stakeholders that have been otherwise left out of the major projects funded by the NC CSC.

Education and Training

The NC CSC Science Agenda (Morisette 2012) called for facilitating communication within and between two main groups: climate scientists and climate science *users* through education and training. The NC CSC's education and training activities have included three main mechanisms:

1. National Conservation Training Center: Coordination and support climate-related courses offered by the National Conservation Training Center (NCTC – nctc.fws.gov)
2. Internal: Providing training for the use of tools and resources developed by the NC CSC and its funded projects
3. Traditional: Supporting the university partners in training students and early career researchers in applying climate information to real world management problems.

The NC CSC worked closely with the NCTC to provide regional offerings of their climate-related courses to federal resource managers, indigenous environmental professionals, and scientists. The NC CSC partnered with NCTC to develop new climate-related courses, and provided funding for logistics, NC CSC staff have served as instructors, and the NC CSC has provided travel support for participants.

As the NC CSC developed tools and resources, it also provided training opportunities to help bring these tools to the wider community. The Software for Assisted Habitat Modeling (SAHM) is one such tool and the NC CSC, in partnership with the USGS Fort Collins Science Center, provided training on the use of SAHM twice a year between 2014-2016 (pubs.usgs.gov/fs/2014/3007/pdf/fs2014-3007.pdf). The NC CSC also supported training for ST-Sim, a spatially-explicit simulation modeling software that is being used by the center. Finally, the NC CSC provided training to early-career climate professionals on the research and tools developed by the FSAs.

The third fundamental mechanism for NC CSC's Education and Training work included partnering with universities in training students and postdocs (n=78). This included working with undergraduate and graduate students through co-teaching, providing guest lectures, and creating class projects for courses across the NCUC (Table 3). NC CSC staff members have also mentored Skills for Undergraduate Participation in Ecological Research (SUPER) students at Colorado State University, USDA REEU and NSF GRIP interns, and have partnered with NASA DEVELOP students who share a portion of the NC CSC workspace on campus. Details on the NC CSC training activities are provided in Table 4.

Table 3: Students/Postdocs/Early Career Researchers Supported

undergraduate students	19
graduate students	35
postdocs	23
early career researchers	1
Total	**78**

Table 4: NC CSC training activities (continued on p. 20).

Title	Mechanism	Dates	Location	Summary
Climate Smart Conservation	NCTC	Sept. 9-11, 2014	Fort Collins, CO	Provided 2 instructors
Climate Smart Conservation	NCTC	Jan. 27-29, 2015	Santa Fe, NM	Provided 2 instructors
Climate Smart Conservation	NCTC	TBD, fall 2017	Bismarck, ND	Provided 2 instructors and logistic and travel support
Climate Smart Conservation for Tribes	NCTC with Bureau of Indian Affairs	July 28-30, 2015	Rapid City, SD	Provided 2 instructors and one guest lecturer and contract support for indigenous instructor

Title	Mechanism	Dates	Location	Summary
				(coordinated with BIA on travel support)
Climate Change Vulnerability Assessment for Tribes	NCTC with the Choctaw Nation of Oklahoma	Oct. 26-28, 2015	Santa Fe, NM	Provided 2 instructors and one guest lecturer
Climate Change Vulnerability Assessment	NCTC	Sept. 30-Oct. 2, 2014	La Crosse, WI	Provided 2 instructors and logistic and travel support
Climate Change Vulnerability Assessment	NCTC	April 22-24, 2014	Jackson, WY	Provided 2 instructors and logistic and travel support
Climate Change Vulnerability Assessment	NCTC	Aug. 27-29, 2013	Shepherdstown, WV	Provided 1 instructor
Software for Assisted Habitat Modeling	Internal	Sept. 9–10, 2014 March 24–25, 2015 Sept. 8–9, 2015 March 22–23, 2016 Sept. 6–7, 2016	Fort Collins, CO	Utilizing NASA funding and in-kind staff support, hosted and conducted training, provided travel support to some participants
State and Transition Modeling with ST-SIM	Internal	Sept. 16, 2014	Fort Collins, CO	Utilizing contractor support and in-kind staff support, hosted and conducted training, provided travel support to some participants
State and Transition Modeling with ST-SIM	Internal	Fall 2017	Fort Collins, CO	Utilizing contractor support and in-kind staff support, hosted and conducted training, provided travel support to some participants
CSU Natural Resource Ecology Lab seminar series	Traditional	Fall 2012	Fort Collins, CO	Hosted, organized and covered travel expense for guest lecturers
CSU Natural Resource Ecology Lab seminar series	Traditional	Fall 2016	Fort Collins, CO	Hosted, organized and covered travel expense for guest lecturers
Early Career Professional training	Internal	May 18-19, 2015	Fort Collins, CO	Planned and taught a 2-day training for students/early career professionals
National CSC Student and Early Career Training	CSC network	Nov. 2-3, 2016	Amherst, MA	Staff on planning committee. Provided two facilitators. Funded 3 students to attend.
Climate Smart Conservation, Climate Adaptation Workshop	NCTC	April 11-13, 2017	Durango, CO	Provided 1 instructor and workshop coach.
Natural Resource Consortium Training (CSU Extension plus other natural resource units on campus)	Internal	July 11-12, 2018	Colorado Springs, CO	Provided 2 instructors for training on incorporation of climate into management actions – theory and tools.
Student mentoring	Traditional	ongoing	within NCUC member institutions and with PIs	Varies: center operations, research projects, interns

PhenoCams

Phenology, which is the study of seasonality and the timing of life-cycle events, is a crucial link between climate and natural resources. For instance, as migrating animals often follow the "green wave" of vegetation, phenology influences the timing and location of their migration. The NC CSC has partnered with the AmericaView program (americaview.org) to establish phenology cameras, or "PhenoCams" –stationary cameras that transmit images from the field to a central server every 30 minutes – at strategic locations across the region (eleven cameras are currently stationed in Colorado, Wyoming, Montana, North Dakota, South Dakota, Kansas, Nebraska, and Iowa). Both the raw data from PhenoCams and general analyses of vegetation greenness (index of foliage density) are freely available via the National PhenoCam Network (phenocam.sr.unh.edu/webcam). These cameras build capacity by providing data that bridges the scales of local observers (e.g., citizen scientists) and satellite imagery, and allowing researchers to have access to land conditions 365 days a year. Moreover, the NC CSC has developed and documented protocols for establishing off-grid cameras in additional locations in the future. This program was discontinued by the NC CSC in 2017, although a few staff members and affiliated researchers still maintain their own cameras.

Tribal College Student Phenology Observations

Collaborator Daniel Wildcat (Haskell Indian Nations University) and his students have undertaken data collection efforts to establish the concept of phenology walks and trails on tribal lands, and refine protocols for further collection efforts. Students have begun making observations of culturally and traditionally significant plants to generate data sets for use in climate change impact assessments. Thus far, over 400 positive phenophase observations (i.e., visual confirmation that a phenological status is present) from the Wakarusa Wetlands Indigenous Trail have been uploaded to Nature's Notebook (data can be downloaded from USANPN).

Helping to Facilitate the Indigenous Phenology Working Group

The Indigenous Phenology Working Group grew out of discussions about phenology (the study of the timing of plant and animal life-history events) at the first three Rising Voices workshops and was catalyzed by a phenology breakout group session at Rising Voices 3 (June 29-July 1, 2015). The goal of this group is to bring stories, data, and communities together to achieve a more complete understanding of phenology and its relationship to climate and human communities. The group uses a standing monthly call as a platform to:

- Share information
- Facilitate discussions about phenology
- Build relationships among a wide group of interested people
- Identify information needs and think collectively about how to provide the best tools and resources for addressing those needs

The working group encourages respect for traditional ecological knowledge (TEK) and following guidelines for collecting and sharing TEK (such as those by the Climate and Traditional Knowledges Workgroup, climatetkw.wordpress.com/guidelines), and engaging with tribal college students. This group is a grassroots organization, consisting of those interested in phenology observations either on tribal lands and/or on species of cultural importance. The group is open to anyone interested and is currently organized through monthly calls and a listserv facilitated by the NC CSC. This listserv currently has 113 subscribers.

Communications and Outreach Activities

Partner and management audiences for NC CSC communications include state, academic, federal, and tribal groups who have an interest in CSC science, product synthesis, management support, and tools produced. Specifically, this includes staffers, tribal representatives, students, researchers, national offices, regional management groups, and others. Outreach and communications were developed through a multi-media approach including website design and maintenance, social networking, production of news stories and updates, public seminars and presentations given at local meetings, and more, with goals of information accessibility and science translation.

Through the years, several communication specialists worked to serve these audiences by building and maintaining a variety of communication venues.

Website

The website was built to be the primary face of the NC CSC with information on science, data, partnerships, and products. Regularly updated offerings included a slideshow feature on the home page, a live feed to the center's Twitter feed, news, events, and the latest information about funded projects and established partnerships.

Twitter

The NC CSC created its Twitter page in 2012 and since then amassed several hundred followers and over 800 tweets. The social media site has served as a platform for connecting with fellow scientific organizations, members of the climate science community, tribal groups, managers, community leaders, and students, to name a few, but also serves as another public face of the center.

Facebook

NC CSC's Facebook page was created in mid-2016 and has so far generated followers among students and early career professionals, peers within the scientific community, and research and management audiences. Posts include early career resources, NC CSC updates, and climate research news of interest to scientists and local communities.

Blogs and Other Media Content

Collaborations with universities and research groups led to the production of several blogs and inline media stories, including posts to a CSU ecology blog, a national early career blog, High Country News, CSU's news service, and others. For a time, the NC CSC also participated in the production of press releases.

Newsletter

The NC CSC began producing a quarterly newsletter in the fall of 2014. Each newsletter focused on one of the center's three foundational science areas – climate drivers, ecological impacts, and adaptation – plus one issue per year on capacity building. The newsletter was sent to a list of subscribers, printed and handed out at the center and at conferences, and utilized to gather regular updates from particular research teams. In 2018, the format was changed to include briefer, more timely updates on a monthly basis from a broader array of projects. Regular sections included staff and project updates, upcoming events and announcements, science highlights, management connection highlights, and product/publication summaries.

NC CSC Monthly Check-ins

The NC CSC held monthly check-in webinars with presentations from an NC CSC research team or a collaborator on recent work, tools, or resources of interest. A round robin update from select funded researchers followed, allowing those joining the webinar to stay in touch with NC CSC research.

YouTube Page

Monthly check-in webinars and other presentations, workshops, and conferences were regularly recorded and posted to the NC CSC YouTube channel. This allowed attendees as well as those who had missed meetings to catch up. Additionally, many of the videos were made public, so any science webinars – for example, on drought monitoring tools – were widely available and often referenced in other applications, such as in teaching environments.

Project Reporting and Highlights

The Project Tracking Dashboard (PDash), developed by the National Climate Change and Wildlife Science Center, was used for project management and tracking, including metadata, reports, deliverables, and data management plans. As an example, PDash generated automated reminders that were sent to funded PIs when reports were due or as reminders to fill out the monthly Google Docs spreadsheet, instituted so each project could report on monthly activities, needs, and synergies before each monthly webinar. Additionally, information about upcoming meetings, collaborations, public engagement strategies, and other nationally-relevant activities were collected regularly and reported to the USGS/NCCWSC for potential use in press materials.

More specifically, one of the most regularly-occurring tasks of the center was to use an "activity reporting" Google form to track staff engagement and ad-hoc (unfunded) activities for potential stories and Highlights reporting. Highlights and stories were also gathered from above-mentioned webinars and PDash spreadsheets.

MailChimp

Though frequently used for newsletters, MailChimp was also used to connect directly with managers and science partners in the region. Many of the NC CSC's collaborators, as well as representatives of agencies, tribes, and other target audiences, were added to segmented mailing lists used for different purposes. Mailings were frequent but took place on an ad hoc basis – for example, funding announcements, invitations to upcoming meetings, significant strategic updates to the center, etc.

Meetings and Visits

When the NC CSC interacted with research partners, members of Congress, students, and others, the communication team often supplied NC CSC business cards, postcards, informational handouts, topical one-pagers, and other handouts that told stories about the center's collaborations, science, and research efforts. This included handouts and posters brought to meetings, as well as regularly replenished supplies of handouts in the office for visitors.

Additional Efforts

Whereas on-the-ground communications and engagement efforts, such as trainings and workshops, require a very tailored approach, it was also recognized that more universal findings and tools could be shared with broader audiences. To that end, there was a planned effort at the center to re-formulate the NC CSC brand, build templates for presentation materials and science briefs, supply recurring news content (such as monthly EDDI and LERI news updates from Rangwala, Dewes, and team), and best

practices for the development of science communication products. There was also some discussion of communications and engagement staff serving as a resource on a case-by-case basis for project-related communications efforts. Recognizing that this would take additional time and effort, the main goal of the communications staff remained on a broader level, with project-level assistance provided occasionally.

Congressional Outreach

Over the past seven years, NC CSC university staff have visited Washington DC several times for Congressional outreach, in coordination with University Directors and staff from other CSCs in the network. These trips were meant to keep federal sponsors informed of the progress the CSC network was making. These trips often included a visit to NCCWSC headquarters, USGS, DOI and OMB. This visits were funded using university resources.

2015 Open Science Conference

The NC CSC hosted an Open Science Conference on May 20-22, 2015 in Fort Collins, CO. The theme of the conference was "Integrating Research and Management of Change from the Mountains to the Plains." The conference brought together approximately 120 attendees, including representation from:

- Colorado (70 of the attendees) and other states in the domain (about 50 of the attendees)
- NCUC institutions: CSU, Montana State University, Iowa State University, the University of Montana, the University of Colorado Boulder, the University of Nebraska, and the University of Wyoming
- Managers, government agencies, and NGOs (46 of the attendees)
- Students (27 of the attendees)
- A wide array of disciplines

The conference offered research scientists and stakeholders the opportunity to actively engage with the NC CSC. Topics included bringing western science, indigenous perspectives, and land management needs together to both assess what the NC CSC has achieved so far and chart a path forward to build on successes and fill gaps in current understanding. This conference contributed to efforts to inform the ReVAMP framework and advance the mission of the center to bring the best available research to bear on land management actions in the region.

A number of key themes emerged from the conference, including: producing actionable science and making research useful and usable by resource managers, collaboration that incorporates the end user from the first stages of research, creating climate-smart plans for drought planning and management in partnership with indigenous colleagues, recognizing and working through climate uncertainty, and understanding the context of on-the-ground management.

Ad Hoc Support

The NC CSC does a significant amount of work to provide the best-available climate science that goes beyond the FSAs, funded projects, and formal capacity building efforts. These are referred to as "ad hoc" activities, which include a wide range of services like presenting guest lectures, consulting on research methods, providing summaries of historical and projected climate data and information, and advising university students. Ad hoc support activities are typically initiated by a partner or partner organization and, as a result, generally fall outside the directed and funded work of the NC CSC. However, NC CSC staff oftentimes draw on the lessons, products, and expertise from these more formal research activities in order to respond to partner needs on an ad hoc basis.

The NC CSC did not initiate a concerted effort to track ad hoc activities until late in 2016, so the activities summarized here are only a subset of the services provided to partners and partner organizations over the seven-year hosting period.

Despite the delayed start in tracking ad hoc activities, the NC CSSC has logged 221 individual activities, which are classified into seven categories: consultation, convening/coordination, instruction/training, presentations, product development/information requests, student interaction/mentoring, and service (see Table 5 for definitions and examples of each category). The service category was not added until 2017. These categories often overlap (e.g., a guest lecture to an undergraduate class could be considered a presentation or student interaction), so although it is not an ideal classification scheme, it does provide insight into the distribution of the types of activities the NC CSC is engaged in (Figure 7).

Table 5: Ad hoc support category descriptions and examples.

	Total	Description	Examples of deliverables
Consultation	32	Activities that entailed advising or providing input on a particular topic for a partner or partner organization.	Letters of support for proposals, advice on survey development, providing suggestion on model input and parameterization.
Convening/Coordination	52	Similar to consultation, but generally involve connecting or working with more than one partner or partner organization where consultation is provided, but the major effort is related to bringing the groups together and facilitating the conversation and consultation.	Organizing or steering committees for regional meetings (e.g., Greater Yellowstone Ecosystem, National Adaptation Forum), facilitating standing conference calls or webinars.
Instruction/Training	14	Activities wherein NC CSC staff serve as instructors or provide support for a larger training activity.	See details in the section on training.
Presentations	37	Similar to instruction/training activities, this form of ad hoc support generally involves giving a single lecture or webinar presentation outside of a formal training exercise.	Guest lectures, invited keynotes.
Product Development/Information Request	64	Activities involving the creation of a research or decision-support tool or publication, or the provision of data or summarized information.	Climate summaries; often produced for inclusion as climate information to a larger report or data used in scenario planning exercises.
Student Interaction/mentoring	11	Activities involving both formal and informal involvement with undergraduate and graduate student training and student mentoring.	Graduate Student committees, providing climate-related information for student projects and research.
Service	11	Activities done in service to another organization, agency or unit.	Manuscript review, serving on committees.
Grand Total	211		

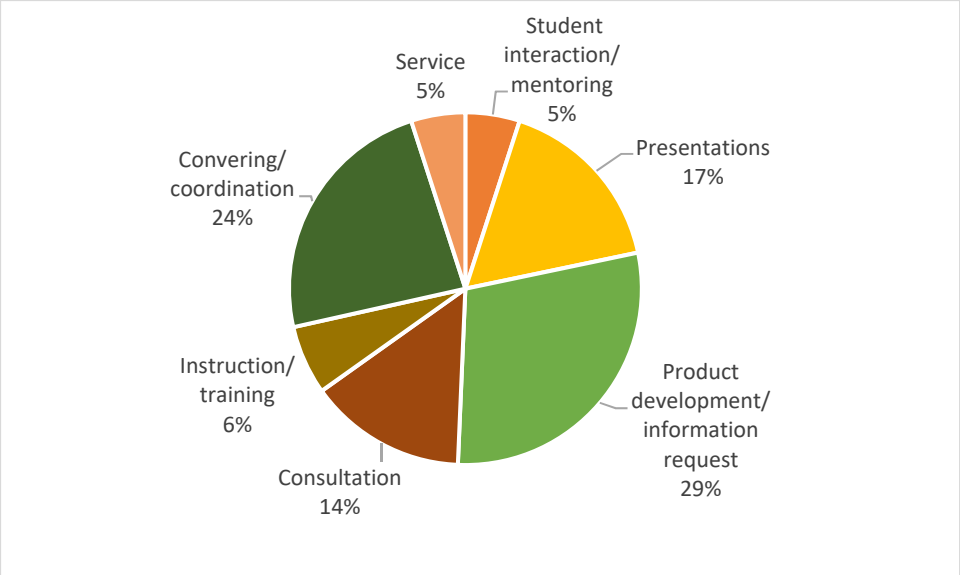


Figure 7: Breakdown of NC CSC's ad hoc support activities (n=221)

Collaborative Efforts

It is important to recognize other regional climate resources located in the North Central U.S. Collaboration and coordination between these resources can help realize the value of the federal investment in this region for delivering climate services to multiple sectors.

Collaboration between the NC CSC, WWA, and USDA Northern Plains Climate Hub

The NC CSC works closely with the NOAA-sponsored Western Water Assessment (WWA) and the USDA Northern Plains Regional Climate Hub (NPRCH) to bring each organization's unique strengths to the table to serve this state and region. Table 6 defines many of the characteristics of these organizations and describes the individual stakeholders and key resources. For example, WWA focuses on water resources and hazards, the NC CSC focuses on fish, wildlife and cultural heritage resources, and the NPRCH focuses on agriculture and forestry.

Table 6: Summary of the main components of the WWA, GPRCH, and NC CSC (continued on p. 28).

	WWA	NC CSC	NPRCH
Primary Users, Stakeholders, Constituents	Mixed, Fed, City, Regional, Residential Water users and water resource managers	Department of Interior and state land managers and tribal environmental professionals	Agricultural and natural resource managers (ranchers, farmers, forest land owners)
Sectoral Focus	Water Resources, Urban, Hazards, Science Policy	Land, water, fish and wildlife, and cultural heritage resources	Agriculture and Forestry
Direct Agency Support	$730k	$2.0M	Reallocation
Budget Line	NOAA Climate Program Office, Office of Oceans and Atmospheric Research	USGS National Climate Change Wildlife Science Center	USDA Department level across six agencies
Start Year	1999	2011	2013
Mission	Making climate science more usable in decision making; more research oriented	To provide the best possible climate science to Department of Interior land managers & provide university and USGS researchers an opportunity to work with an engaged and proactive applied management community	To develop and deliver science-based, region-specific information and technologies to agricultural and natural resource managers, and communities, that enables climate-smart decision-making
Research to Operations Continuum	Research	Research and applied	More applied; transfer information and knowledge to end users for reducing risk and increasing resilience
Operations and Staff	Director, Program Manager, two regional engagement experts	USGS Director, University Director, USGS staff, University staff	ARS Director, with support of FS and NRCS staff
Federal University Partnership	Single University with NOAA ESRL	NCUC (9 universities) with USGS's National Climate Change Wildlife Science Center	USDA collaborations with Agricultural Experiment Stations and Cooperative Extension
Funding Model	Through NOAA OAR	Through USGS NCCWSC	Across USDA six agencies
Stakeholder Advisory Committee	Eight members from academia, federal agencies, non-profit sectors drawn from outside of our direct SH pool for the most part	Federal employees and Tribal representative, run jointly with the NPRCH	Federal employees and tribal representatives, run jointly with the NC CSC

	WWA	NC CSC	NPRCH
Data and Model Capabilities	Hydrology modeling, climate data, paleoclimate, decision modeling	Ecological response modeling on fish and wildlife	Spatially explicit data on ag, fire modeling, water quality data, ag clearing house
Social Science Capabilities	Usable science, evaluation, science policy	Data and decisions pertaining to primarily public land management	Adaptation and vulnerability analysis
Biological-Physical Science Capabilities	Snow hydrology, climate modeling, downscaling, energy	Ecosystems, ecology	Soil health, nutrient cycling, greenhouse gases, agricultural modeling
Geographic Focus	UT, WY, CO	Upper Missouri Basin (MT, ND, WY, NE, SD, CO, KS)	Northern Plains (ND, SD, NE, MT, WY and CO)
Temporal Focus	Seasonal to 2100	DOI and Tribal management planning horizons	Working lands management planning horizons

Each group focuses on serving its own constituency to help them understand the implications of a changing climate. However, the three groups coordinate to realize efficiencies where possible, thus allowing the development of a more holistic understanding of regional climate issues. For example, users have access to an integrated set of climate information, through the Western Water Assessment Intermountain West Climate Dashboard (wwa.colorado.edu/climate/dashboard.html), which expanded the footprint of the dashboard to cover the NC CSC and USDA Hub regions. All three entities share this link on each respective website. Strong collaboration across these three institutions is facilitated through group staff retreats every six months. Ongoing efforts are underway for collaborative research papers and research projects. Through collaboration, the delivery of climate services across multiple sectors in the region represents a good working example of how federal investments can be leveraged and deployed at the regional level to help decision makers adapt to climate.

Joint Stakeholder Committee

Further coordination has been achieved between the NPRCH and the NC CSC by establishing a Joint Stakeholder Committee (JSC) shared by the two groups. This committee has recently been reorganized in 2018.

The purpose of the JSC it to:

1) Provide guidance, coordination, and collaboration for the work of the USDA Northern Great Plains Regional Climate Hub and the DOI NC CSC.
2) Facilitate communication and awareness of federally-funded climate-related work throughout the general region defined by the union of each center's area of interest, and
3) Aid in the consolidation of priorities and information exchange between federal agencies and to various state, tribal, and other entities in this area.

The objectives of this joint stakeholder committee are to ***maximize*** **communication, awareness and coordination** among regional federal agencies while ***eliminating*** **redundancy and stakeholder fatigue**. The JSC is comprised of regional representatives from relevant federal agencies charged with natural resource management, providing services and science support. JSC membership is voluntary, but each federal agency listed in the roster generally provides at least one member. It is recognized that regions

and boundaries vary across agencies, which may necessitate an agency having more than one representative. The co-chairs facilitate and organize at least one face-to-face meeting per year, with webinars or conference calls throughout the year as needed. While the JSC is made up of representatives from federal organizations, it is recognized that each member of the JSC will likely have a broader non-federal partner and stakeholder list that can be a source of information and capacity for each federal entity. These relationships are valuable pathways for conveying information to and from this group.

Coordination with the Landscape Conservation Cooperatives

The four LCCs that overlap with the NC CSC are the Great Northern, Southern Rockies, Plains and Prairie Potholes, and Great Plains. Each of these has a representative on the JSC[3]. Since its inception, the LCCs have been a key partnership for the NC CSC (as described above and shown in Figure 3). Where the NC CSC has a greater emphasis specifically on climate science delivery, the LCCs focus more generally on defining research needs for conservation, and on science and tool delivery to support conservation outcomes.

Starting in 2016, in order to help connect the landscape-scale conservation activities of the LCCs with its climate science capacity, the NC CSC has worked with the four LCCs to establish liaison teams. These liaison teams focused on communication between LCC and NC CSC leadership to enhance the development of collaborative work, and integrate climate science with management needs to result in the co-production of information. These liaisons helped leverage existing efforts and expertise of the USGS, staff at the NC CSC, and the NCUC to more directly contribute climate science collaboration and support to priority LCC activities and topics.

Indigenous and Native American Collaboration

Native American and indigenous interests and relationships to the environment and their cultural heritage is a key element of the NC CSC's work. As such, the NC CSC collaborates with Native Americans in the North Central region, as well as Indigenous Peoples across the U.S., and the NC CSC's philosophy has been to integrate this collaborative work into FSAs, funded research, capacity building efforts, ad hoc support, and the JSC (as described above). The center has fostered a working partnership with a number of entities and reservations in the region, which has resulted in the co-production of research, planning processes, assessments, and knowledge across a range of topics. Examples of the formal groups the NC CSC has established collaborative efforts with include the Intertribal Council on Utility Policy (COUP), Inter-Tribal Buffalo Council (ITBC), Wind River Reservation, Haskell Indian Nations University, Indigenous Peoples Climate Change Working Group (IPCCWG), and the Rising Voices cooperative hosted by the University Corporation for Atmospheric Research (UCAR). These collaborative efforts have led to contributions to the 3rd and 4th National Climate Assessments Indigenous Peoples chapter and Great Plains/Northern Great Plains regional chapters, development of the Wind River Reservation Climate and Drought Summaries, funding of research projects (such as The Wind River Indian Reservation's vulnerability to the impacts of drought and the development of decision tools to support drought preparedness project), wind energy feasibility report for the Missouri River Basin, phenology walks in Native American landscapes, and a number of co-designed proposals and workshops to enhance the connection between research and Native American and Indigenous management needs.

The NC CASC has supported several regional and national training and convening activities. Examples of this include: the Institute for Environmental Professionals Climate Adaptation trainings, the Tribal Climate Camp, the Northwest Tribal Climate Summit at Flathead Reservation, Confederated Salish and Kootenai Tribes workshop on drought and flood planning, workshops at Menominee College, NCTC trainings for tribes on Climate Smart Conservation and Vulnerability Assessment, and the National

Adaptation Forum tribal track. We also played a role in the cross-CASCs planning group to bring on the BIA-supported tribal liaisons.

Eco-Drought Actionable Science Working Group

The National Climate Change and Wildlife Science Center is engaging in an Ecological Drought initiative. This effort includes an actionable science working group that is intended to connect scientists and managers to identify science needs for drought-related decisions and ultimately provide managers with a drought adaptation and planning toolkit. The NC CSC helped to initiate and facilitate this Eco-Drought Actionable Science Working Group (EDASWG) in parallel and consultation with a social science advisory group. This two-year effort was used to develop an operational framework for the EDASWG employing an integrated social-ecological approach to identify the relevant research questions and data needs. The initial meeting took place in September 2016 and is continuing through 2018.

Leveraging

- Colorado State University has provided office space to the NC CSC and contributed to the renovations and furnishing of the offices. Colorado State University contributed approximately $70,000 to the renovation of office space and furniture.
- The Natural Resource Ecology Laboratory at Colorado State University has contributed support in the administrative area of budget and contract management of the funds allocated to other non-federal institutes receiving support from the NC CSC.
- Colorado State University has contributed an in-kind contribution of a lowered Indirect Cost Rate (IDC) on the host agreement. The IDC was negotiated at 31.3% for the period of June 2011 through November 2016 and modified to 34% for funding received from November 2016 through the end of October 2017.

  If the full overhead rate were applied to the host agreement, total direct charges would have been:
  Yr1: $405,950 (compared to $453,889)
  Yr2: $343,030 (compared to $387,966)
  Yr3: $342,030 (compared to $388,835)
  Yr4: $298,537 (compared to $339,745)
  Total savings: ~$200,000
- The NC CSC has also leveraged a research scientist position by housing Gabriel Senay, a scientist at the EROS Data Center, at the NC CSC.

Connections with partner institutions have led to many instances of project support both in the form of monetary and in-kind contributions. NC CSC staff have written successful proposals that have led to receiving research funding from non-USGS sources, for example from the Bureau of Land Management and Department of Defense. Other types of leveraged support include contributions from partner organizations, such as the National Park Service, Colorado Natural Heritage Program, Colorado Parks and Wildlife, and Tribal organizations. These contributions include salary, data processing and storage, time spent, consultations and technical assistance, project funding, outreach capabilities, and student support.

In total, over the first seven years of the NC CSC, we have more than doubled the investment (~$3,400,000) of the USGS by leveraging funds, raising additional research dollars and in-kind support.

Training and Spin-off Projects Generated

Many of the NC CSC's products are created to outlast the center's involvement in the work. Examples include training programs, which serve as examples and provide materials for future

workshops and trainings carried out by other organizations. NC CSC adaptation projects, such as one in southwest Colorado, are specific instances where social-ecological climate resilience materials have been requested by other groups, like the Colorado Natural Heritage Program (CNHP), Rocky Mountain Research Station, the Mountain Studies Institute, and the U.S. Forest Service.

Another example of the longevity of NC CSC work is the creation of spin-off projects that use data and products created by NC CSC research. The Colorado Bureau of Land Management and the CNHP are using NC CSC scenario plans to create an adaptation strategy for pinyon-juniper landscapes, which dominate forest ecosystems in many parts of the Rocky Mountains. Data products like EDDI historical data, R scripts, and Multivariate Adaptive Constructed Analogs (MACA) downscaled climate data have been utilized in non-CSC work, as well. These are but a few in a long list of examples of how the NC CSC has provided plans, materials, data products, and other footholds for work carried out by a wide variety of non-CSC entities.

Partnerships and Collaborations

Both the NC CSC's leveraging capacity and its provision of guidance and materials result from the partnerships and collaborations inherent in the work done at the center. Projects are planned with cross-organizational partnerships and actionable products in mind. These partnerships fall into categories that include the NCUC universities that host funded researchers and the NC CSC itself, the organizations that house many of the NC CSC's FSA scientists, the groups of stakeholders and external organizations for whom the NC CSC creates its materials and trainings/workshops, and the groups doing related work that both partner with and benefit from NC CSC efforts. Both intentional partnerships, built into project planning, and unintentional partnerships, such as interactions with other groups and resulting from the dissemination of NC CSC information, have woven the NC CSC's work into the broader scope of climate science in the North Central U.S. and established the center as a well-known research organization in the region.

Key Products and Tools

There are numerous products and services produced by the NC CSC since its inception, as summarized in the previous sections and detailed in the appendices. This section highlights some of the more significant products from the center.

NC CSC Paleoenvironmental Database

Drawing in large part on the work of Cathy Whitlock at Montana State University, the NC CSC Paleoenvironmental Database serves as an archive of Pleistocene proxy records, metadata and derivative products (e.g., chronologies, vegetation and climate reconstructions) and provides a resource for environmental research, facilitating data viewing, synthesis and joint analysis of multiproxy datasets. These paleoenvironmental data help place the ecological landscapes of today into the context of an ever-changing and non-stationary climate.

Estimates of Evapotranspiration

Water availability is a significant component of climate-driven stressors in the North Central U.S. Climate model projections all show warming throughout the region but variable and uncertain trends with respect to precipitation. However, even without a decrease in precipitation, warming will influence the water stress and available moisture for plants in the region. Evapotranspiration (ET) is not only important for water budget studies and irrigation water use planning, but can also be used for mapping

drought impact (i.e., extent and severity). It is along these lines that the NC CSC has invested effort and focused collaboration on estimates for evapotranspiration.

Researchers at the NC CSC are analyzing monthly ET data from satellite products developed by the USGS Earth Resources Observation and Science (EROS) Center to better understand the spatio-temporal dynamics of drought evolution in the U.S., along with other drought indicators. Senay et al. (2016) provides the detailed methodology of satellite-based ET for the Colorado River. These satellite products provide spatially explicit historic and near-real-time estimates of actual ET (AET). These efforts are complemented by the Climate Drivers FSA's work with the University of Colorado-Boulder and NOAA on the climate-driven Evaporative Demand Drought Index (EDDI). Together, EDDI and AET indicate, respectively, how "thirsty" plants are and how much they are actually "drinking."

Customizable Climate Primers

Climate Primers is an R package with the purpose of generating a summary document of historical and future climate for a site or a region. A summary contains maps, graphs, statistics, and historical versus future comparisons. The package is designed to be used in any system that runs R. When generating a summary document, the package is flexible and configurable to allow for various sources of climate data, and for producing various kinds of document content. The effort grew out of interactions with the National Park Service Climate Change Response program to produce custom climate summaries for a specific park. These climate summaries have also been used for both the Rocky Mountain and Intermountain Adaptation Partnerships. (See story on pg. 5 for more.)

Evaporative Demand Drought Index (EDDI)

The Evaporative Demand Drought Index was developed in recent years to exploit the strong physical relationship between evaporative demand (E_0), also called "atmospheric thirst," and the amount of water actually lost through evapotranspiration (ET). This strong relationship between atmospheric demand for water and ET allows the EDDI team to calculate the drought index frequently based on the latest atmospheric data. EDDI has been proven as a strong indicator of both rapidly-evolving flash drought and sustained drought, and it may be used in concert with drought indices like the U.S. Drought Monitor to portray a more complete picture of drought. The EDDI website offers a suite of tools, a user guide, and more.

Landscape Evaporative Response Index (LERI)

Unlike EDDI, the Landscape Evaporative Response Index (LERI) is an experimental drought-monitoring and early warning guidance tool that measures soil to determine actual evapotranspiration (ET_a). LERI works by determining deviations in the ET_a from the land surface as compared to "normal" conditions for the available period of satellite observations (2000-present). ET_a is a measure of how much water is actually leaving the land's surface through evaporation and transpiration (via plants) and entering the atmosphere, an important metric for tracking water use efficiency and plant and soil stress. LERI complements other drought monitoring indices by providing an additional data set – specifically, high-resolution (1 km) remotely-sensed estimates of soil dryness. LERI can be useful in verifying modeled soil moisture products. This tool is also expected to have early warning potential for agricultural and ecological droughts, flash droughts, and wildfire risk. Learn more about LERI.

Operational Simplified Surface Energy Balance (SSEBOP)

The Operational Simplified Surface Energy Balance (SSEBop) was developed in 2013 by Gabriel Senay and others as a revision of the Simplified Surface Energy Balance (SSEB). SSEBop is a method for estimating actual evapotranspiration (ET_a) using satellite data. This method has been applied for many

purposes, including famine early warning and drought monitoring in regions with minimal ground-based data as well as mapping water use and ET_a estimation in the U.S. at regional and continental scales. SSEBop has been used to produce ET_a maps over large extents at lower spatial resolution (1km) than other metrics using less parameterization.

Key Regionally-focused Publications

The FSAs and the management-focused projects have all produced an impressive array of publications. In addition to that work, through the host institution agreement, and with USGS staff time and NCUC members, there have been a few select publications that exemplify the mission of the center to connect climate science with resource management in a regional context:

- ***Colorado Climate Change Vulnerability Study (Report, 177 pp.)***
  Gordon and Ojima, eds. with partial funding through the host institution agreement
  wwa.colorado.edu/publications/reports/co_vulnerability_report_2015_final.pdf
- ***National Climate Assessment: Chapter 19, "Great Plains"***
  Ojima and Shafer, eds. with partial funding through the host institution agreement
  nca2014.globalchange.gov/report/regions/great-plains
- ***National Climate Assessment 4*: Northern Great Plains Chapter (forthcoming)**
  Collaborating authors and workshop hosted by the NC CSC
  https://www.globalchange.gov/content/nca4-planning
- ***Colorado Wildlife Action Plan Enhancement: Climate Change Vulnerability Assessment (Report, 129 pp.)***
  Decker and Fink with in-kind modeling support provided by NC CSC staff
  cnhp.colostate.edu/download/documents/2014/CO_SWAP_Enhancement_CCVA.pdf
- ***Climate Change in Wildlands (Book)***
  Hansen, Monahan, Theobald, and Olliff, eds. with partial funding through the Ecological Impacts FSA and collaboration from staff on Chapter 4
  islandpress.org/book/climate-change-in-wildlands
- ***Collaborative Modeling Workspace article***
  Morisette, J.T., Cravens, A.E., Miller, B.W., Talbert, M., Talbert, C., Jarnevich, C., Fink, M., Decker, K., Odell, E.A. (2017). "Crossing boundaries in a collaborative modeling workspace." Society & Natural Resources, 30(9), 1158-1167.
- **Colorado Bureau of Land Management: Social Vulnerability Assessment**
  McNeeley et al. with funding from the CO BLM and NC CSC
  http://nccsc.colostate.edu/sites/default/files/COBLM_Social-Vulnerability-Assessment_Final-Report_4-9-18.pdf
- **BAMS Article: Regional Climate Response Collaboratives: Multi-institutional support for climate resilience**
  Authors are directors and affiliates of the NOAA RISA (Western Water Assessment), NC CSC, and USGS Northern Plains Climate Hub
  https://journals.ametsoc.org/doi/10.1175/BAMS-D-17-0183.1

Impacts Foundational Science Area

Outputs from the Impacts FSA have included substantial progress in assessing climate and land use change impacts across the NC CSC domain. These include: quantifying the rates of land use change in and around the protected area systems, determining the extent of fragmentation in major ecosystems, assessing evaporative demands, and predicting forest ecosystem responses to climate change.

Social Vulnerability Assessment Framework and Methodology

As part of a broader effort to increase the ability of federal agencies to understand and adapt to changes in climate variability and hazard profiles, the Colorado Bureau of Land Management commissioned an on-going research effort to gather and analyze information on the potential climate-related vulnerabilities of the numerous communities and businesses that rely upon the state's 8.4 million acres of BLM-managed public lands. This project developed a framework and methodology for undertaking a social vulnerability assessment and produced a comprehensive report and three fact sheets which summarized results. http://nccsc.colostate.edu/project/colorado-bureau-land-management-social-vulnerability-assessment/

Drought Summaries

In order for land managers to begin to make forward-looking drought plans, they need to be updated regularly on what the current conditions are and what the outlook is for the coming season. In response to this, NC CSC researchers created a template for quarterly climate and drought summaries to be used in a particular location. They also produced the first few quarterly outlooks for a group of stakeholders, while teaching them how to do it themselves, so they can continue on once funding has expired. This effort supported drought impact analysis across the Wind River Indian Reservation.

TopoWx

TopoWx is a gridded dataset of daily ~800-m interpolations of minimum and maximum topoclimatic air temperature for the conterminous U.S., based on elevation variables and MODIS land skin temperature. The resulting temperature data is proving to be a valuable tool for spatially-explicit ecological and hydrological modeling. The TopoWx product is publically available and currently being used by stakeholders in the region, such as resource managers at Yellowstone National Park (Rodman, 2015). This dataset was produced by the Numerical Terradynamics Simulation Group at the University of Montana with funding from the Climate Drivers FSA. The NC CSC is actively utilizing these data as a key gridded historical climate dataset for parameterizing ecological responses to past temperatures.

Land Surface Phenology and PhenoCams

The international community has agreed upon the use of coupled PhenoCam sites and in-situ observations as the primary validation for land surface phenology products (Morisette, 2010); as such, PhenoCam activity is occurring in coordination with the Committee on Earth Observation Satellites Land Product Validation subgroup (CEOS LPV – lpvs.gsfc.nasa.gov) and the USA National Phenology Network (usanpn.org). The NC CSC has played a lead role in deploying eleven phenocams in the region (described above) and developing and documenting protocols for acquiring and analyzing additional phenology data through MODIS and Landsat. A USGS/National Association of Geoscience Teachers intern made significant advances with the latter in determining the field of view of the phenocam to allow direct comparison with remotely sensed data on a pixel-by-pixel level. Other NC CSC researchers are advancing that work, which is considering how to better understand migration with a multi-scale approach from animal movement data, phenocams, satellite products, and climate models (Miller et al. 2015).

Intermountain West Climate Dashboard - Western Water Assessment

This tool is lead and maintained by the NOAA-sponsored Western Water Assessment (WWA). WWA, in collaboration with the NC CSC and the NPRCH, extended their original Climate Dashboard covering three states (Utah, Wyoming, and Colorado) to produce an extended dashboard that covers the domain of the North Central U.S. The dashboard provides an array of climate- and water-related maps and

graphics that are regularly updated to reflect current conditions: wwa.colorado.edu/climate/dashboard.html.

Community Collaborative Rain, Hail, and Snow Network

CoCoRaHS (pronounced KO-ko-rozz) is a grassroots volunteer network of backyard weather observers of all ages and backgrounds working together to measure and map precipitation (rain, hail and snow) in their local communities. It is hosted by CSU's atmospheric sciences department. By using low-cost measurement tools, stressing training and education, and utilizing an interactive website, the aim is to provide the highest quality data of precipitation for natural resource, education and research applications. The NC CSC has contributed to CoCoRaHS by providing rain gauges to stakeholders so they can participate in the effort.

HPRCC Quarterly Regional Climate Outlooks

This effort is led by the NOAA-sponsored High Plains Regional Climate Center (HPRCC). These Regional Climate Outlooks offer an engaging two-page snapshot of recent weather and climate events and anomalies; discusses regional weather impacts on the region's ecosystems and economy; and offers a climate forecast for the coming three months. This publication is developed in partnership with many federal, state, local, and academic partners. It is released in September, December, March, and June. Each quarter HPRCC solicits input for the outlook from the community. The NC CSC collaborates with funded investigators, other USGS centers, and the LCCs to provide input on the regional ecological impacts. The NC CSC also points stakeholder to the quarterly outlook when it is published.

Awards

The NC CSC was recognized with an Honorable Mention at the 2016 Climate Adaptation Leadership Awards for work on a Colorado Wildlife Action Plan Enhancement in collaboration with the Colorado Natural Heritage Program and Colorado Parks and Wildlife. This work was done based on a recommendation from the Association of Fish and Wildlife Agencies (AFWA) to incorporate climate change impacts into 10-year State Wildlife Action Plans (SWAPs). Exposure, sensitivity, and adaptive capacity of key species and habitats were addressed in the assessment with goals of identifying the types and locations of significant climate change impacts as well as identifying which ecosystems are more or less vulnerable in order to inform prioritized management.

In 2017, the second year the Climate Adaptation Leadership Awards were offered, the NC CASC received an Honorable Mention in the Broad Partnership category for a project on drought preparedness at the Wind River Indian Reservation in Wyoming. The project was a collaboration with tribal leaders, agencies, and universities to create a drought management plan for the Wind River Indian Reservation in Wyoming. The reservation had faced severe water shortages in recent droughts and prior to this engagement, had not developed a comprehensive drought plan. Partnerships, effective collaboration, and social science contributed greatly to the success of this project. Outcomes included several drought summaries and a drought dashboard.

The NC CSC housed one of the twelve NASA DEVELOP centers found across the United States, and further acted as the hub for DEVELOP activities in the Inter-mountain West from 2012-2016. The focus of the Colorado DEVELOP team is utilizing NASA EOS to support natural resource management and ecosystem science across western landscapes. The Colorado team distinguished themselves in the DEVELOP program by using remote sensing with integrative geospatial modeling to map invasive tamarisk along the Arkansas River in southeastern Colorado, forest structure and pine beetle-induced

tree mortality in Fraser Experimental Forest, and wetlands in the Cache La Poudre watershed following the devastating High Park Fire of June, 2012. The team not only provided important baseline information at landscape-scales, but it also evaluated the resilience and adaptive capacity these systems have under changing climates. The Colorado DEVELOP team earned a national award from NASA DEVELOP and Science Systems and Applications, Inc. in 2013 for excellence in research and their contribution to the NASA DEVELOP program.

NC CSC Office Roles and Responsibilities

The NC CSC strives to achieve an atmosphere where the federal and university employees work collaboratively. Yet, in order to maintain efficiency and accountability, the NC CSC has established the following outline for roles and responsibilities.

Host institution internal administrative responsibilities:

- System administration of (including ordering, configuring, and maintaining) all non-USGS computers in the center, as well as networking and data storage on campus
- Office management, including assignment of personnel to desks, shared office policies (mainly for room A318), furniture for the center (including deck), and maintaining and ordering supplies (including printer, copier, and whiteboard)
- Management and administration for all subcontracts and service agreements from CSU to consortium members and others.
- Annual reporting for the host institution agreement
- Campus-wide engagement in the CSC
- Legislative visits and briefings

Host Institution primary responsibilities in collaboration with USGS:

- Establishing and engaging the NCUC university partnerships and ensuring that input from the consortium proactively looks to contribute to the CSC mission
- Communication and reporting on work done by the NCUC
- Management of university employees
- Communication with the USGS on organizational structure and hiring plans of host institution employees working at or closely with the CSC

USGS primary responsibilities in collaboration with the host institution and the NCUC:

- Working with the host institution and with the other NCUC universities to develop the scientific research and capacity at the center, both through staff at the CSC and funded investigators
- Promote the CSC on inquiries from Congress, OMB, other Federal and USGS staff on CSC program activities, funding, and scientific results and representing the CSC research program activities to a wide range of customers and stakeholders
- Establishing and engaging the Joint Stakeholder Committee and ensuring that input from the JSC is used to help guide the science done at the CSC
- Management and involvement with USGS-administration of all funds going from USGS to the host institution
- Gathering input from the NCUCs, the JSC, relevant LCCs, and USGS centers in the region to compile a research agenda for the center
- Develop plans to utilize CSC science to provide information to DOI, State, and Tribal resource

managers in the region
- Manage USGS employees at the NC CSC
- Communicate with the host institution on organizational structure and hiring plans of USGS employees working at the CSC
- Bring relevant USGS research and capacity to bear on the activities of the center

Details for individual staff members are posted on the NC CSC website (nccsc.colostate.edu/staff).

Budgets

The amounts allocated in core budget categories from FY12-FY16 are depicted below (Figure 8). In general, the host agreement comprises about 25% and research activities (both USGS and university) comprise about 50-70% of the total center budget each year. The percentages in the categories are similar for FY 17 and FY18. We can provide updated figures if requested.

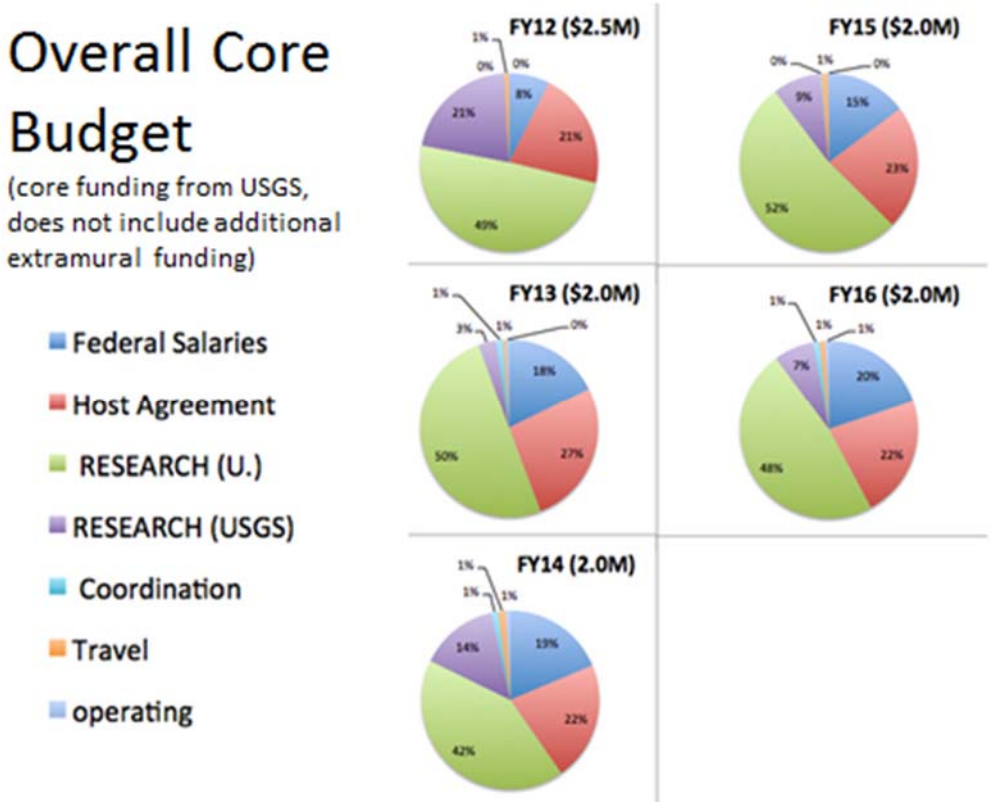


Figure 8. NC CSC core budget categories FY12-FY16.

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