Department of the Interior

NORTH CENTRAL CLIMATE SCIENCE CENTER

2017 Annual Report

Submitted by:

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Introduction to the North Central Climate Science Center

The North Central Climate Science Center (NC CSC) is one of eight regional CSC's under the National Climate Change and Wildlife Science Center (NCCWSC). Our mission is "To provide the best available climate science and tools to inform natural resource management within the North Central domain." The NC CSC is a collaborative, applied research group that works with others across our domain to unite climate science with management decisions. The North Central University Consortium (NCUC), comprised of nine university partners in the region, provides foundational science needs and additional opportunities for integration with climate science users.

The NC CSC is dedicated to being a "Resource for Vulnerability assessment, Adaptation, and Management Projects" (Figure 1). The ReVAMP concept is a centralizing theme that coordinates research done through the NC CSC and provides a mechanism by which the NC CSC can help serve stakeholder needs. Co-development of research products with managers working in partnership with research groups is a key component of our ReVAMP development efforts. The ReVAMP concept builds on three Foundational Science Areas led by the North Central University Consortium members. The three Foundational Science Areas offer an integrated approach to informing resource managers and researchers in our region:

- ***Climate Drivers:*** Understanding and quantifying drivers of regional climate changes.
- ***Impact Analysis:*** Assessing impacts of climate change on the natural resources of the region and the resulting vulnerability of social-ecological system components.
- ***Adaptation:*** Characterizing vulnerabilities, adaptive capacity, and management response options of communities and natural resource managers.

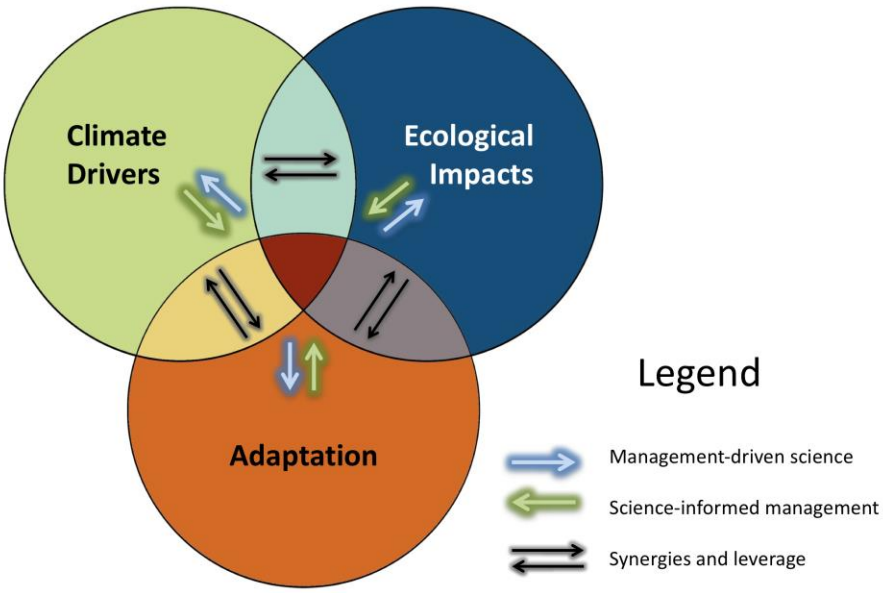

Figure 1. The three synergistic NC CSC foundational science areas include climate drivers, ecological impacts, and adaptation.

Fundamental Science for the ReVAMP: Foundational Science Areas Research

NC CSC Foundational Science research incorporates the three concepts within a social-ecological system framework. This approach allows for better integration of research findings into a solution-oriented decision-making process due to the enhanced awareness of social dimensions of changes and impacts across the North Central region. This framework allows for specific research to be carried out within certain disciplinary domains while providing a platform to link various findings within the system framework.

The NC CSC used directed funds in 2017 to support NCUC efforts to continue work in the three foundational science areas to address climate drivers (with a focus on drought), impacts, and adaptation. The details of that work are given in the following three sections.

Although the three foundational science areas and other management-focused projects (see below) are funded out of the USGS-side of the NC CSC budget, and not from the hosting agreement, CSU administers and is responsible for oversight of all of the grants, and therefore, activities and deliverables are reported on in this report.

Foundational Science Area #1: Evaporation, Drought, and the Water Cycle across Timescales: Climate Foundational Science for the North Central Climate Science Center

Team Lead: Imtiaz Rangwala, NOAA
Co-Investigator(s): Candida Dewes, University of Colorado, Boulder

The Foundational Science Team identifies and addresses climate science challenges that are important for ecologists and land managers in the North Central region. Drought is a dominant driver of ecological, economic, and social stress in the region, and is expected to be a major mode in which the impacts of climate change will be manifested in the region. The specific goal of this project is to improve the understanding of drought, and in particular, to improve the climatic data (temperature, soil moisture, and other aspects of the water balance) that is being used to make projections of future ecological conditions in the regions. We will work to translate this scientific knowledge and data so that it is useful for land managers through the development of future drought scenarios that are supported by the quantitative data and tailored to the needs of the different landscapes within our region.

Related Activities and Deliverables

- Web platform developed for the Evaporative Demand Drought Index (EDDI) tool (https://www.esrl.noaa.gov/psd/eddi/)
- Research and outreach engagement on the Wind River Indian Reservation Drought Preparedness project
    - Study on understanding the climatology of mountain snow in relation to the reservation's water needs
    - Study on the micro-drought of 2015
- Development of high-resolution projections of evaporative demand for the NC CSC region
- Update and publication of station-based Pan Evaporation data across the continental US

- Peer-reviewed journal publication of the research describing sources of uncertainties in future projections of evaporative demand
- Continuing engagement on the Southwest Colorado Social Ecological and Climate Resilience project
- Engagement with the Ecodrought working group and research support
- Continuing and new engagements with NC CSC staff and stakeholders

Foundational Science Area #2: Impacts and Vulnerability: Connecting Climate Drivers to Management Targets

Team Lead: Andrew Hansen, Montana State University
Co-Investigator(s): Arjun Adhikari, Montana State University

Rates of climate change vary across the Great Plains and Rocky Mountains, as do the responses of ecosystems to these changes. Knowledge of locations of rapid climate change and changes in ecosystem services such as water runoff and ecological productivity are important for crafting locally relevant adaptation strategies to cope with these changes. This project will assess how climate, ecosystem processes, and vegetation have shifted over the past half century and how they are projected to change in the coming century under various future scenarios. These analyses will be done within areas centered on natural vegetation cover such as in and around Federal and Native American lands. These areas of natural vegetation provide ecosystem services important to local people and knowledge of patterns of climate and ecological change are important to resource managers. The results of the project will be used by the NC CSC Adaptation team to work with local stakeholders to develop strategies for coping with and adapting to the projected changes.

Related Activities and Deliverables

- Participated in NC CSC five-year review
- Prepared land use change report for the Wind River Indian Reservation Drought Project
- Collaborating with the Climate Drivers Team on downscaled climate data to model the habitat for major tree species across the domain
- Developed new approach for analyzing climate change impacts on water balance in Greater Wildland Ecosystems (GWE) and land allocation types across the domain
- Compared habitat suitability of water-limited tree species under two sets of predictors led by potential evapotranspiration (PET) derived from two methods
- Presented webinar on land use change to the NASA LCLUC program
- Presented a “Lunch time expeditions” talk on the GYE at the Buffalo Bill Museum, Cody, WY

Foundational Science Area #3: Characterizing Adaptive Capacity of Stakeholder Communities and Informing Management Options

Team Leads: Dennis Ojima and Shannon McNeeley, Colorado State University

The purpose of this research is to understand how different federal and tribal natural resource managers experience and deal with drought in cross-jurisdictional landscapes that contain public and private operations on or near DOI, USDA/US Forest Service, and/or tribal lands in the region. The goal of this proposed project is to develop a better understanding of both drought social-ecological system (SES) vulnerabilities, risks, and responses in high-risk, multi- jurisdictional landscapes across the North Central

domain, extending from the Rocky Mountains into the Great Plains. Our research poses the following questions: How do different resource managers from the Department of Interior (DOI), other federal agencies, and tribal communities perceive and characterize drought risk in the same geographic area? How are their respective grassland/rangeland, fish and wildlife, and forest management decisions affected by those drought risk perceptions? What are their differential capacities for responding to and preparing for drought risks? To investigate these questions, we will: 1) document local DOI/tribal resource managers' risk perceptions of drought impacts of various land and resource management activities across a variety of management targets over the domain, 2) characterize how those risk perceptions and responses correspond with or differ from each other and with scientific drought indicators, and 3) identify respective decision calendars and the appropriate temporal/spatial scales for climate information needs in order to provide rigorous, localized drought science and tools to managers.

Related Activities and Deliverables

- Wind River Indian Reservation (WRIR) Project
    - Several publications and reports have been completed, or are in review, during this reporting period
    - McNeeley article in a special issue of Weather, Climate and Society which illustrated the underpinnings of tribes' barriers to sustainable climate change adaptation
    - Published final report on the initial findings of the DRAI interviews at WRIR
    - In collaboration with the Climate Drivers FSA and the broader WRIR team, published a paper in Climate Risk Management on the anatomy of the 2015 irrigation season at WRIR
    - Scientific integration effort for the social-climate-ecological integrated assessment and report writing
- Northwest Colorado and southwest South Dakota
    - Built on initial results reported in a comparative case study of local drought vulnerabilities and response capacities and deepened the focus on the social and ecological contexts under which bison are managed on NPS-managed land
    - In collaboration with the Capacity Building team, explored how qualitative case studies can inform ecological response models
    - Document how qualitative case studies can ground simulations models in local contexts and help make them more structurally realistic and useful
- Colorado BLM social vulnerability assessment
    - Published a review paper of social science approaches to vulnerability assessment, which informed current assessment
    - Conducted a document review of resource management plans, resource advisory council notes, and other policy documents
    - Conducted a geospatial analysis of multiple publically available socio-demographic and economic datasets, and BLM field office records on grazing the recreation usage patterns and intensity
    - Documented community patterns, characteristics, and connections to BLM-managed resources and to develop spatial indicators of potential sensitivities to climate variability and change
    - Completed two qualitative case studies in two field office management areas
    - Completed analyses from the document review, spatial indicators and case studies
    - Completed final report and fact sheets for phase 1 of project
    - Started planning phase 2 of project

Foundational Science Area Teams

Financial support

The foundational science work was re-supported in 2017. The NC CSC (through USGS-managed funds) provides resources to each team. Each team has a leader who is responsible for organizing the work within that area as well as connecting the work within that area to both of the other foundational science areas and into the ReVAMP science delivery mechanism. Team resources can support time for the team leader, a post-doctoral researcher, and team workshops. It is up to the team lead, working in collaboration with the NC CSC, to utilize the budget to maximize the impact of each team.

Support for the mission of the NC CSC

Finally, it is the ultimate objective of the three Foundational Science teams to support the mission of the NC CSC to deliver the best possible climate-related science to regional resource managers. Currently, the lead investigators for each of the three teams (i.e., climate, impacts, and adaptation) routinely communicate on research efforts and prioritization of research activities to enhance the linkage of research products. This collaboration across teams improves efficiency, understanding and utility for use in natural resource management decision making. With the resources and objectives outlined here, the NC CSC hopes it will be possible to further enhance coordination among teams to develop a more integrated climate-ecological-social system framework.

Management-focused Projects

The NC CSC funds (through USGS-managed funds) competitively selected multi-year 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 and/or investigators. These solicited projects help connect the foundational science work with critical resource management needs and are helping to define the specific capacity that will be built into the ReVAMP framework.

Management-focused Projects Completed in 2017

1. SCALING CLIMATE CHANGE ADAPTATION IN THE NORTHERN GREAT PLAINS THROUGH REGIONAL CLIMATE SUMMARIES AND LOCAL QUALITATIVE-QUANTITATIVE SCENARIO PLANNING WORKSHOPS

Principal Investigator(s):
Amy Symstad, Northern Prairie Wildlife Research Center
Co-Investigator(s):
Brian Miller [Colorado State University North Central Climate Science Center (NC CSC)], Nicholas Fisichelli [National Park Service (NPS)], Gregor Schuurman (NPS), Melinda Koslow (NPS), Andrea Ray [National Oceanic and Atmospheric Administration], Jonathan Friedman (USGS), Erika Rowland [Wildlife Conservation Society]. Partners: Milton Haar (NPS), Mike McNeill [U.S. Forest Service (USFS)], Wendy Ross (NPS), Cami Dixon [U.S. Fish & Wildlife Service (FWS)], Neil Shook (FWS).

Climate change is expressed in both regional climatic shifts (e.g., temperature and precipitation changes) and local resource impacts. Resource management in a changing climate is challenging because future climate change and resource responses cannot be precisely predicted. Scenario planning

is a tool to assess the range of plausible future conditions. However, selecting, acquiring, synthesizing, and scaling climate information for scenario planning requires significant time and skills.

This project has three goals: 1) synthesize climate data into 3-5 distinctly different but plausible climate summaries for the northern Great Plains region; 2) craft summaries of these climate futures that are relevant to local land management units; and 3) apply these local summaries to further develop quantitative climate-resource-management scenarios through participatory workshops and simulation models. This team is engaging with multiple stakeholders in two focal areas within the region: southwestern South Dakota in the vicinity of Badlands National Park, and central North Dakota in the vicinity of Knife River Indian Villages National Historic Site. This effort will increase climate change planning efficiency in the region; promote collaborations across jurisdictions; and develop a prototype for a novel, efficient, and replicable form of scenario planning that could serve additional management units.

2017 Activities, Deliverables and Progress

- Presentations at professional meetings and public outreach (see appendix)
- Completed simulation model, reviewed by management partners, simulation model manuscript preparation, submission, and revisions
- Final project report submitted
- Assembled team for extension project planning (see "Informing Climate Change Adaptation Planning in National Parks" – below)
- USGS Data Release: Miller, B.W., Symstad, A.J., Frid, Leonardo, Fisichelli, Nicholas, and Schuurman, G.W., 2017, State-and-transition simulation model of rangeland vegetation in southwest South Dakota (1969–2050): U.S. Geological Survey data release, at https://doi.org/10.5066/F7T1524X.

2. BUILDING COLLABORATION BETWEEN THE NORTH CENTRAL CSC AND REGIONAL PARTNERS THROUGH LIAISON TEAMS

Principal Investigator(s):
Geneva W Chong (USGS Northern Rocky Mountain Science Center)

The North Central Climate Science Center (NC CSC) is committed to bringing the best possible climate science to bear in order to inform decisions made by Department of the Interior (DOI) planners and other land and resource managers across the country. To help accomplish this mission, key partnerships have been established between the NC CSC and the DOI Landscape Conservation Cooperatives (LCCs) in the North Central region of the U.S. Whereas the eight Climate Science Centers have a greater emphasis 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.

In order to help connect the landscape-scale conservation activities of the LCC network with its climate science capacity, the NC CSC has worked with four regional LCCs and its University Consortium to establish liaison teams. These liaison teams will focus communication efforts between LCC and NC CSC leadership to enhance development of collaborative work, integrating climate science with management needs to result in co-generated information. These liaisons will help leverage the existing efforts and expertise of the USGS, staff at the NC CSC, and the NC CSC University Consortium to more directly contribute climate science collaboration and support to priority LCC activities and topics.

The objective of this collaboration is to focus on increased engagement and communication, as called for in the National Academy of Science review of the LCCs, to 1) take advantage of the LCCs' existing and ongoing distillation of partner needs and 2) bring to bear on those needs existing NC CSC and USGS climate related science. Learn more about this collaboration and the team members here: http://nccsc.colostate.edu/meeting-stakeholder-needs

2017 Activities, Deliverables and Progress

- FY17 activities included: individual conversations with the Liaison Coordinator and Liaisons, meeting and workshop participation, proposal development, and membership on advisory teams
- Overall, from the initial phone calls to the continuation of mostly unfunded liaison work in FY18, the response to the Liaison Project has been positive.
    - In the Northern Rockies, liaisons are pursuing funding with the USFWS National Elk Refuge (NER), Wyoming, to initiate studies on elk aggregation and potential disease transmission as influenced by climate effects on plant productivity and supplementary feeding. At a minimum, a pilot project will occur in FY18. This work will contribute directly to elk and bison management that is governed by the Bison and Elk Management Plan and the NER Comprehensive Conservation Plan.
    - In the Southern Rockies area, which includes Colorado, the liaison has developed a brief prospectus for a potential synthesis (FY18) related to issues and challenges for Pinyon-Juniper ecosystems, which are of broad concern in the region.
    - In the Great Plains, which includes Nebraska and Kansas, an FY17 grassland-climate modeling project has expanded into FY18 work resulting from stakeholder concerns regarding the expansion of mesquite in southern Great Plains grasslands. The liaison is now involved in developing (FY18) bioclimate models of mesquite distribution, and then using GCM scenarios (similar to the grassland-climate modeling project) to project potential future distribution of mesquite in the southern Great Plains based on climate change.
    - In the Plains and Prairie Potholes, liaisons are supporting strategic science planning, which includes development of communication and analysis tools that multiple LCC partners can use to communicate the benefits and consequences of landscape conservation across multiple socioeconomic sectors. State partners have expressed interest in the LCC pursuing this framework, and the liaisons are committed into FY18.

3. CAPACITY BUILDING IN THE NORTH CENTRAL CLIMATE SCIENCE CENTER DOMAIN

Principal Investigator(s):
Dennis Ojima (Natural Resource Ecology Laboratory, CSU) and Brian Miller (USGS)
Collaborator(s):
Dan Wildcat, Indigenous Peoples Climate Change Working Group, Haskell Indian Nations U.; Eric Wood, USGS EROS; Debbie Deagan, AmericaView program, Montana State University; Geneva Chong, USGS NC CSC and Northern Rocky Mountain Science Center

In addition to the major projects funded by the North Central Climate Science Center (NC CSC), selected through the formal USGS solicitation process, and the directed funds going to the Foundational Science Areas, there remains a need within the north central domain to support work that builds capacity among stakeholders that have been otherwise left out of the major projects funded by the NC CSC. In this proposal, we focus on building such stakeholder capacity building through two projects. One is to expand the Indigenous Phenology Network (IPN). The other is to continue deployment and analysis of

PhenoCams in the Missouri River Basin through our AmericaView partnership. Colorado State University's Natural Resource Ecology Lab (CSU NREL) is the host location for the NC CSC. The efforts proposed here will be managed through the host institution staff and facilities. CSU is responsible for ensuring that the IPN and PhenoCam activities are, to the furthest extent possible, integrated with and leverage the other efforts of the NC CSC. CSU is responsible for overseeing the deployment of PhenoCams; AmericaView and StateView partners will oversee the operation of PhenoCams and the investigation of the integration of PhenoCam data with satellite imagery. CSU will also be responsible for evaluating the potential for expanding these initial efforts beyond the work described here (with support from either the NC CSC or other sources) and providing guidance on if and how that future work would fit within the mission of the NC CSC.

2017 Activities, Deliverables and Progress

- Phenocam work – maintenance of existing webcams, transfer of remaining phenocams to other accounts at the close of the project (December 2017)
- Continuation and expansion of the Indigenous Phenology Network (IPN) – monthly calls of a group of people interested in understanding phenology on lands and species of importance to native peoples
- Held workshop focused on strategic planning for the Indigenous Phenology Network (November 6-8, 2017)
- In collaboration with NCTC, Miller was an instructor/coach for two workshops in Durango, CO (April 11-13, 2017) – Overview of Climate Smart-Conservation and Climate Adaptation Workshop
- Development of two-part training (webinar series and in-person training), in collaboration with NASA Applied Remote Sensing Training program, on tools for scenario-based ecological forecasting
- Development of multiple proposals

Continuing Management-focused Projects

1. NATURAL RESOURCE MANAGEMENT DECISION-MAKING UNDER CLIMATE UNCERTAINTY: BUILDING SOCIAL-ECOLOGICAL RESILIENCE IN SOUTHWESTERN COLORADO

Principal Investigator(s):
Nina Burkardt and Rudy Schuster, USGS Fort Collins Science Center
Co-Investigator(s):
Renée Rondeau (Colorado State University, Colorado Natural Heritage Program); Betsy Neely (The Nature Conservancy - TNC); Marcie Bidwell (Mountain Studies Institute - MSI); Laurie Yung (University of Montana - UM); Carina Wyborn (UM); Rudy M. Schuster (USGS); John Sanderson (TNC); William Travis (University of Colorado - CU); Daniel Williams (USDA Forest Service Rocky Mountain Research Station); Daniel Murphy (University of Cincinnati)

In southwestern Colorado, climate change includes higher temperatures, more frequent and prolonged drought, accelerated snowmelt, larger and more intense fires, more extreme storms, and the spread of invasive species. These changes put livelihoods, ecosystems, and species at risk.

To help human and natural communities cope with climate change, this project is creating opportunities for scientists, land managers, and affected residents to learn from each other and identify actions that each can take individually or collectively to reduce the negative impacts of climate change in the San

Juan and Gunnison Basins in Colorado. These adaptation strategies and the processes that created them are being documented by the participating scientists to assist communities elsewhere in identifying goals and actions that conserve key species, ecosystems, and resources, and address the needs of local communities and natural resource managers in the face of a changing climate.

2017 Activities, Deliverables and Progress

- Social Ecological Resilience and Changing Landscapes Webinar Series (January-April 2017) https://www.fs.fed.us/rmrs/social-ecological-resilience-and-changing-landscapes-webinar-series
- Finalized landscape reports for both river basins
- Poster at National Adaptation Forum (May 2017)
- Co-host Climate Adaptation Workshop with National Conservation Training Center and NC CSC (March 2017)
- Present framework and results to TNC conservation staff
- Support integration of climate science into partner projects

2. SURROGATE SPECIES FOR WETLAND-DEPENDENT BIRDS IN THE PRAIRIE POTHOLE REGION: SELECTION, EVALUATION, AND MANAGEMENT APPLICATION IN THE FACE OF CLIMATE CHANGE

Principal Investigator(s):
Susan Skagen (U.S. Geological Survey, Fort Collins Science Center) and Barry Noon (Colorado State University)
Co-Investigator(s):
Helen Sofaer (Colorado State University); Valerie Steen (USGS Fort Collins Science Center); Ben Rashford (University of Wyoming); John Stamm (USGS South Dakota Water Science Center); Kevin Doherty (USFWS, Prairie Pothole Joint Venture); Neil Niemuth, (USFWS, Habitat and Population Evaluation Team); Cami Dixon (Zone Biologist, USFWS Region 6, National Wildlife Refuge System); Mark Chase (Director, USFWS Natural Resource Program Center); Natalie Sexton (Chief, Human Dimensions Branch, USFWS Natural Resource Program Center); Lee O'Brien (Ecologist, USFWS National Wildlife Refuge System); Socheata Lor (USFWS, Regional Inventory and Monitoring Coordinator), Rick Nelson and Mike Olson (Plains and Prairie Pothole Landscape Conservation Cooperative (PPPLCC))

The Prairie Pothole Region spans parts of North and South Dakota, Minnesota, Montana, Iowa and south-central Canada and contains millions of wetlands that provide habitat for breeding and migrating birds. Because it is the continent's most important breeding area for waterfowl, conservation and management largely focuses on protecting habitat for nesting ducks. However, other wetland-dependent birds also rely on this region, and it is important to understand the degree to which habitat conserved for ducks provides habitat for other species, and how the quality of this habitat will be affected by climate change.

The Surrogate Species team is testing whether waterfowl are effective representatives, or surrogates, for other wetland-dependent birds by predicting how climate change will affect habitat suitability for waterfowl and other species. They are also considering how climate change is likely to affect land-use patterns and agricultural conversion risk, and are using these predictions to identify areas of the landscape where both waterfowl and other species are expected to have suitable habitat in the future. This research will help managers to efficiently direct their resources towards conserving areas that will provide habitat to a broad suite of species.

2017 Activities, Deliverables and Progress

- Continued work on project publications (see Appendix)
- Submitted final report

3. FORECASTING CHANGES IN SAGEBRUSH DISTRIBUTION AND ABUNDANCE UNDER CLIMATE CHANGE: INTEGRATION OF SPATIAL, TEMPORAL, AND MECHANISTIC MODELS

Principal Investigator(s):
Andrew Hansen (Montana State University), formerly: Benjamin Poulter (Montana State University, now at NASA)
Co-Investigator(s):
Peter Adler, Utah State University; Cameron Aldridge, USGS; Bethany Bradley, University of Massachusetts. John Bradford, USGS; Caroline Curtis, University of Massachusetts; Andy Kleinhesselink, Utah State University; Jen Pierce, Boise State University; Daniel Schlaepfer, University of Wyoming; Eric Thacker, Utah State University Extension. Mary Manning, US Forest Service; Renee Chi, Utah BLM; Robert Means, Wyoming BLM; Steve Torbit, Fish and Wildlife Service.

The future of sage grouse depends on the future of sagebrush, yet there is limited ability to anticipate impacts of climate change on sagebrush populations. Current efforts to forecast sagebrush habitat typically rely on species distribution models (SDMs), which are prone to a variety of well-known weaknesses. However, by integrating SDMs with complementary research approaches, such as historical data analysis and mechanistic models, it will be possible to provide increased confidence in projections of habitat vulnerability to climate change.

The goal of this project is to forecast the effect of climate change on the distribution and abundance of big sagebrush in order to inform conservation planning, and sage grouse management in particular, across the Intermountain West. The novelty of this work is the integration of model projections based on spatial, temporal, and mechanistic relationships between climate and sagebrush cover. The project will culminate in a working group meeting bringing together land managers and researchers to discuss how integrated metrics for climate vulnerability can be used to inform management. The team will take advantage of existing USGS infrastructures already in place to efficiently disseminate our final report to management agencies.

2017 Activities, Deliverables and Progress

- Continued development of manuscripts
- Preparation of outreach/fact sheets for stakeholders
- Development of short video documentary/podcast
- ESA oral presentation

4. THE WIND RIVER INDIAN RESERVATION'S VULNERABILITY TO THE IMPACTS OF DROUGHT AND THE DEVELOPMENT OF DECISION TOOLS TO SUPPORT DROUGHT PREPAREDNESS

Principal Investigator(s):
Cody Knutson, University of Nebraska-Lincoln
Co-Investigator(s):
Mitchel Cottenoir, Tribal Water Engineer, Shoshone and Arapaho Tribes Office of the Tribal Water Engineer; Jennifer Wellman, Hydrologist, Wyoming Experimental Program to Stimulate Competitive

Research (EPSCoR) Coordinator at Wind River Reservation; Shannon McNeeley, Research Scientist, Colorado State University/North Central Climate Science Center (NC CSC); and Mark Svoboda, Climatologist and Leader of the Monitoring Program, NDMC, University of Nebraska-Lincoln Project Management Team (PMT): The PIs listed above plus Northern Arapaho Tribal Liaison, Gary Collins, and Al C'Bearing, Baptiste Weed, Jim Pogue, Office of the Tribal Water Engineer

This project is conducting an interdisciplinary, technical assessment of key social-ecological vulnerabilities, risks, and response capacities of the Wind River Indian Reservation (WRIR) to inform development of decision tools to support drought preparedness. It is also providing opportunities for 1) development of tribal technical capacity for drought preparedness, and 2) educational programming guided by tribal needs, Traditional Ecological Knowledge (TEK), and indigenous observations of drought for tribal members, with a longer-term goal of transferring lessons learned to other tribes and non-tribal entities.

This project has foundational partnerships between the Eastern Shoshone and Northern Arapaho tribes of the WRIR, the National Drought Mitigation Center (NDMC) at the University of Nebraska-Lincoln, the North Central Climate Science Center (NC CSC) at Colorado State University, University of Wyoming EPSCoR, and multiple government agencies and university partners. These partners are working together to develop decision tools to support drought preparedness. Other partners include the USDA Northern Plains Regional Climate Hub and NRCS, the Western Water Assessment at CU-Boulder, NOAA National Integrated Drought Information System (NIDIS), the High Plains Regional Climate Center, US Fish and Wildlife Service, USGS, BIA, Great Northern LCC, and other North Central University Consortium scientists. The project's decision target is a WRIR Drought Management Plan that integrates state-of-the art climate science with hydrologic, social, and ecological vulnerabilities and risks, and identifies response capacities and strategies to support the Tribal Water Code and related resources management.

2017 Activities, Deliverables and Progress

- Social science team
    - Completion of analysis of results of interviews with tribal water and natural resource managers
    - McNeeley presented at the Institute for Tribal Environmental Professionals (ITEP) Climate Adaptation workshop in Billings, MT (August 2017)
    - Staff from the Office of the Tribal Water Engineers Office conducted interviews with representatives from four tribes across the US to better understand how they have conducted drought vulnerability analyses and integrated them into drought plans
    - Drought planning meeting/webinar held with tribal staff, community members, and the project team (January 10, 2017)
    - Quarterly social science team teleconferences held
    - Team participated via teleconference in meetings of the Agricultural Resources Management Planning team on the WRIR
    - Contributed to publication on the 2015 irrigation season
- Physical Science Team
    - Evaluation of historical drought information for the WRIR
    - Updated the Drought Risk Atlas through 2016
    - Work on better understanding snow process in the region, and how they might be changing
    - Continuation of production of quarterly climate summaries
    - Quarterly team teleconferences held

- Ecological Impacts Team
    - Collected biological data at eight sites regarding big sagebrush ecosystems – data processed and analyzed (in collaboration with the University of Wyoming), working on deliverable
    - Completed land use and land cover (vegetation) analyses (in collaboration with Montana State University)
- Project Integration
    - Development of outreach materials
    - Final project meeting – November 14-15, 2017
    - Compiling material to deliver to the Tribal Water Engineers office for website
    - Draft drought plan created

5. UNDERSTANDING DYNAMICS OF LAND USE SWITCHING WITH SATELLITE AND FIELD LEVEL DATA IN CONTEXT OF CLIMATE VARIABILITY

Principal Investigator(s):
Peter T. Wolter [Iowa State University], Christopher J. Anderson [Iowa State University], Hongli Feng [Michigan State University], David Hennessey [Michigan State University]
Co-Investigator(s):
Kaylan Carrlson (Manager of Conservation Planning, Ducks Unlimited, Inc.); Martha Kaufmann (Managing Director, Northern Great Plains, World Wildlife Federation US); Heather Johnson (Regional Private Lands Coordinator, US Fish and Wildlife Service); Scott McLeod (N. Dakota Private Lands Coordinator, US Fish and Wildlife Service); Adnan Akyüz (N. Dakota State Climatologist); Peter Bauman (S. Dakota State Univ. grassland extension specialist); Juan M. Murguia (Dept. of Agric. & Applied Economics, N. Dakota State Univ.); Ben Rashford (Dept. of Agric. & Applied Econ., Univ. of Wyoming); Susan Skagen (USGS, Fort Collins, Colorado); Rick Nelson (Plains and Prairie Pothole Landscape Conservation Cooperative).

What remains of the United States prairie ecosystem is threatened by economic forces and a changing climate. Grassland conversion to cropland in the Dakotas would imperil nesting waterfowl among other species and further impair water quality in the Mississippi watershed. This team is working with grassland conservation managers to better target the use of public and private funds allocated toward incentivizing grassland preservation on private lands in the Dakotas. They are assembling data on historical land switching in the area and on land conversion costs, and are analyzing crop vulnerabilities to weather and climate change.

The team is working to provide practical analytical tools to assess the likelihood of grassland conversion to cropping and of the costs of protecting these lands under different climate and economic scenarios. These tools, together with insights they are obtaining from partners in the area allows them to work with land conservation managers to identify lands to target for grassland protection incentives under alternative climate and economic conditions. Outputs will be used to collaborate with land conservation managers when comparing strategies for ensuring that lands providing high wildlife, habitat and hunting benefits at low conservation cost are conserved while private landowners are happy to forgo land use alternatives.

2017 Activities, Deliverables and Progress

- Manuscript preparation – land conversion costs out of grassland in the Dakotas

- Collaboration developed with SD State University to consider impediments to more technically efficient grassland management strategies
- Three presentations at the annual meeting of Agricultural and Applied Economics Association (AAEA) based on analyses of survey and focus group meeting data (July 2017)
- Continued work (in collaboration with Auburn University) on grassland easements as tools for reducing grassland conversion
- Documentation of protocols to identity historical grassland baselines in the Northern Great Plains
- Continuing to refine yield-weather-land use modeling work
- Working on effective easement strategies given landowners' decision making processes
- Continuation of remote sensing assessment of land use changes in the Dakotas
- Analyses of focus group data are ongoing
- Initiated assessment of how farmers process weather events

Newly Funded Foundational Science and Management-focused Projects (FY17)

In 2017, the NC CSC funded (through USGS-managed funds) seven new projects, the three foundational science areas plus four management-focused projects (Figure 2).

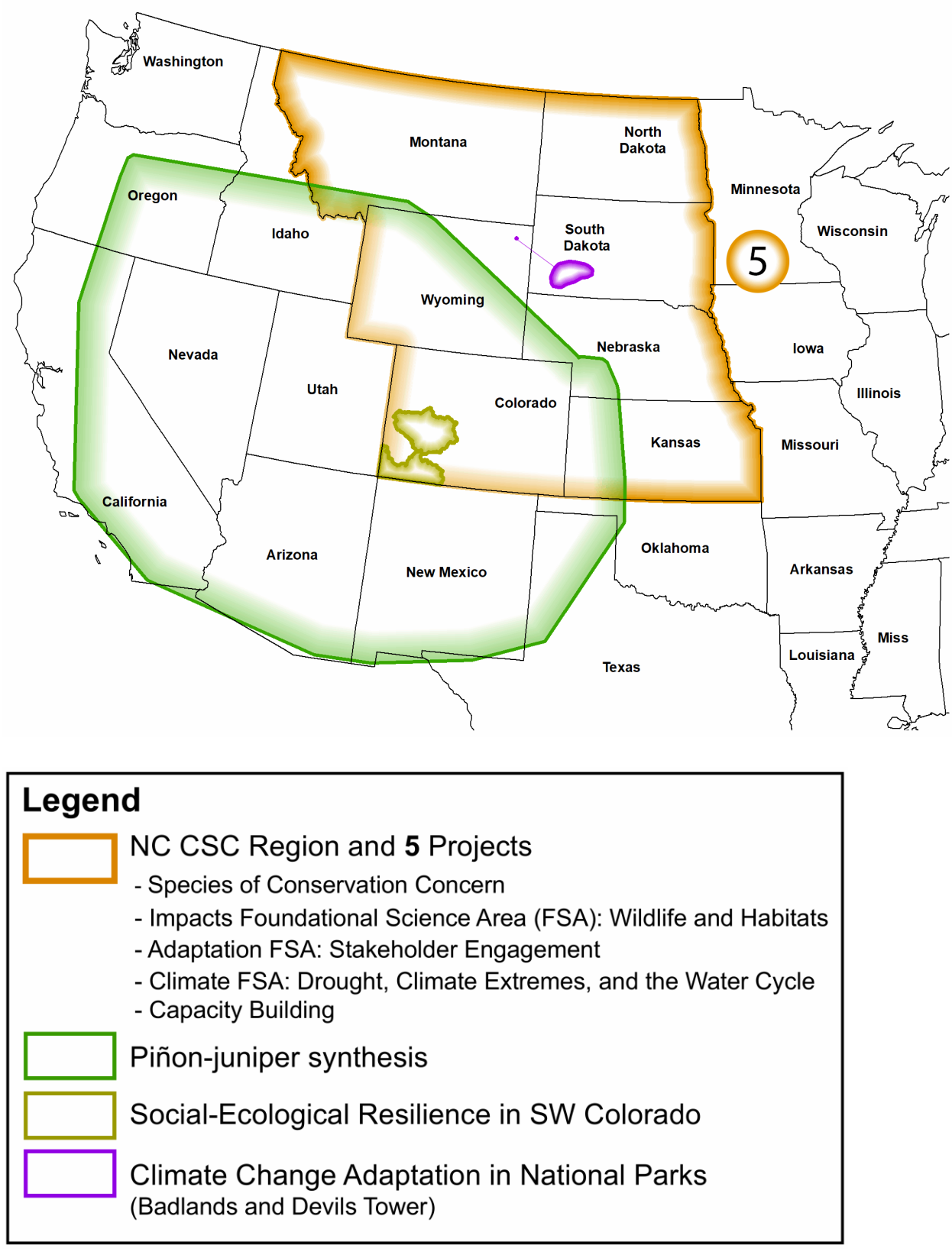

Figure 2: Geographic boundaries of FY17 projects.

1. FOUNDATIONAL SCIENCE AREA: ECOLOGICAL DROUGHT, CLIMATE EXTREMES, AND THE WATER CYCLE IN THE NORTH CENTRAL U.S.

Principal Investigator(s):
Imtiaz Rangwala (CIRES, University of Colorado-Boulder & Physical Sciences Division, NOAA ESRL)
Co-Investigator(s):
Candida Dewes (CIRES, University of Colorado-Boulder & Physical Sciences Division, NOAA ESRL); Joe Barsugli (CIRES/NOAA); Mike Hobbins (CIRES/NOAA); Jeff Lukas (CIRES); Gabriel Senay (EROS, USGS); Daniel McEvoy (DRI); Sanjiv Kumar (Auburn University)

In the North Central U.S., drought is a dominant driver of ecological, economic, and social stress. Drought conditions have occurred in the region due to lower precipitation, extended periods of high temperatures and evaporative demand, or a combination of these factors.

This project will continue ongoing efforts to identify and address climate science challenges related to drought, climate extremes, and the water cycle that are important for natural resource managers and scientists in the North Central region, to support adaptation planning.

To accomplish this goal, researchers will (1) provide data and synthesis on drought processes in the region and on how evaporative stress on ecosystems will change during the 21st century; (2) work with stakeholders to provide climate data that can be used to assess climate impacts; (3) improve the usability of an existing drought early warning and monitoring tool known as the Evaporative Drought Demand Index; and (4) develop a new drought monitoring tool to provide better information about moisture availability in soils. Researchers will also continue to develop and provide information on potential future climate conditions for specific areas that are of interest to stakeholders, in order to understand potential impacts and develop adaptation strategies.

2. FOUNDATIONAL SCIENCE AREA: CLIMATE ADAPTATION STRATEGIES FOR WILDLIFE AND HABITATS IN THE NORTH CENTRAL U.S.

Principal Investigator(s):
Andrew Hansen (Department of Ecology, Montana State University)
Co-Investigator(s):
Arjun Adhikari (Montana State University); Greater Yellowstone Coordinating Committee Subcommittee on Whitebark Pine; Wolverine State Wildland Action Plan Working Group

Researchers with the North Central Climate Science Center have made substantial progress in assessing the impacts of climate and land use change on wildlife and ecosystems across the region. Building on this progress, researchers will work with stakeholders to identify adaptation strategies and inform resource management in the areas that will be most affected by changing conditions.

There are several components of this project. First, researchers will use the Department of Interior "resource briefs" as a mechanism to communicate information to resource managers on climate and land use change and their impacts to resources. These briefs will support coordinated management of ecosystems that contain public, private, and tribal lands. Researchers will also inform the development of a multi-state management plan for wolverine, a species being considered for listing, by providing forecasts of how wolverine habitat might change as climate conditions and land use change. Finally, researchers will work with federal and private resource managers in the Greater Yellowstone Ecosystem

and High Divide regions to develop management guidelines under different possible future climate conditions. This project will support resource managers throughout the North Central region in understanding how conditions might change and identifying potential climate adaptation strategies.

3. FOUNDATIONAL SCIENCE AREA: MAXIMIZING STAKEHOLDER ENGAGEMENT TO SUPPORT CLIMATE ADAPTATION IN THE NORTH CENTRAL U.S.

Principal Investigator(s):
Dennis Ojima (Natural Resource Ecology Lab, Colorado State University)
Co-Investigator(s):
Jill Lackett (CSU); Shannon McNeeley (CSU)

In the North Central U.S., the rate and extent of changing climate conditions has been increasing in recent decades. These changes include shifting precipitation patterns, warming temperatures, and more frequent extreme events, such as droughts and floods. As these changes occur, managers face different challenges and have different needs, depending on the resources they manage. For example, water managers are focused on responding to changes in water availability, while wildlife managers may be more concerned with changing habitat conditions – whether it be for migratory waterfowl, cold water fish, or large mammals.

In the face of these changes, managers are seeking effective strategies for managing resources. To meet this goal, managers require usable and timely information that is relevant to current needs – known as "actionable science." The goal of this project is to identify best practices for developing actionable science results, which are often built around strong stakeholder engagement. Researchers will evaluate the different processes – including mechanisms of stakeholder engagement – that have been employed by the North Central Climate Science Center to provide managers with actionable science that supports climate adaptation planning. By identifying best practices for stakeholder engagement, this project will support the North Central CSC's mission to ensure that their science directly addresses on-the-ground management needs.

4. BUILDING SOCIAL AND ECOLOGICAL RESILIENCE TO CLIMATE CHANGE IN SOUTHWESTERN COLORADO: PHASE 2

Principal Investigator(s):
Nina Burkardt, Fort Collins Science Center; Renee Rondeau, Colorado State University
Co-Investigator(s):
Marcie Bidwell (Mountain Studies Institute); Betsy Neely (The Nature Conservancy); Renee Rondeau (Colorado State University, Colorado Natural Heritage Program); Laurie Yung (University of Montana); Over 100 other local cooperators and partners

In southwestern Colorado, land managers anticipate the impacts of climate change to include higher temperatures, more frequent and prolonged drought, accelerated snowmelt, larger and more intense fires, more extreme storms, and the spread of invasive species. These changes put livelihoods, ecosystems, and species at risk.

Focusing on communities in southwestern Colorado's San Juan and Gunnison river basins, this project will expand opportunities for scientists, land managers, and affected residents to identify actions that can support resilience and adaptation in the face of changing climate conditions.

This project builds on the project "Building Social and Ecological Resilience to Climate Change in southwestern Colorado: Phase 1". Phase 1 focused on developing integrated social-ecological science and adaptation strategies for four target landscapes: spruce-fir forests, pinyon-juniper woodlands, sagebrush scrublands, and seeps, springs and wetlands.

Phase 2 will further advance adaptation strategy development in the region and share the results with other communities, land managers, and decision-makers. Specifically, researchers will identify concrete actions that can be taken to carry out each adaptation strategy, and will develop solutions to address barriers identified by stakeholders in Phase 1 that could impede implementation. Ultimately, this project will result in landscape-scale conservation goals and actions that conserve key species, ecosystems, and resources, address the economic and social systems of local communities, and provide science resources for natural resource managers in the face of a changing climate.

5. ENABLING CLIMATE-INFORMED PLANNING AND DECISIONS ABOUT SPECIES OF CONSERVATION CONCERN IN THE NORTH CENTRAL REGION

Principal Investigator(s):
Molly Cross, Wildlife Conservation Society
Co-Investigator(s):
Shelley Crausbay (Conservation Science Partners); Geneva Chong (US Geological Survey)

The goal of this project is to identify climate-related scientific information needs in the North Central region that will support the management of key species and help avoid species declines. Researchers will work closely with state fish and wildlife agencies, the U.S. Fish and Wildlife Service, tribes, and other relevant natural resource management and conservation agencies to identify priority information needs and to design and implement studies that will address these needs.

Researchers will identify stakeholders, including those engaged by the North Central Climate Science Center USGS Liaisons project. Researchers will then work with stakeholders to identify priority conservation targets. Selected targets will be those that are of high priority to managers, are the subject of a pending or planned decision or action, and for which the decision would benefit from information on climate change exposure, impacts, or adaptation. The outcome will be the identification of key climate science needs that can help advance near-term conservation decision-making. As a final component of the project, researchers will initiate working groups to spearhead the development of research plans that can address these priority, stakeholder-defined climate science needs in the region. These working groups will be comprised of management representatives and researchers affiliated with the North Central Climate Science Center.

By working closely with resource managers to identify information gaps and initiate plans to address these gaps, this project will support the development of usable, relevant, and timely science that directly addresses on-the-ground needs.

6. ECOLOGY AND MANAGEMENT OF PINYON-JUNIPER WOODLANDS: STATE OF THE SCIENCE

Principal Investigator(s):
John Bradford, USGS Southwest Biological Science Center
Co-Investigator(s):
Seth Munson, USGS Southwest Biological Science Center

Pinyon-juniper (PJ) woodlands are a major part of western landscapes, and are utilized for recreation and resource extraction. However, there are competing management objectives relating both to retaining PJ and to ensuring it does not move into non-forested areas. Understanding and evaluating possible management strategies requires a comprehensive evaluation of what we know about PJ systems and how they are influenced by management and climatic conditions. This project will help provide that broad perspective by examining previous research and management practices related to PJ ecosystems to identify what is known, and what remains to be studied.

7. INFORMING CLIMATE CHANGE ADAPTATION PLANNING IN NATIONAL PARKS

Principal Investigator(s):
Amy Symstad (Northern Prairie Wildlife Research Center, USGS)
Co-Investigator(s):
Gregor Schuurman (NPS, Climate Change Response Program); Brian Miller (USGS, North Central Climate Science Center); Chris Church (NPS, National RSS Coordinator, Planning Division); Rene Ohms (NPS, Chief of Resource Management, Devils Tower National Monument)

One of the biggest challenges facing resource managers today is not knowing exactly when, where, or how climate change effects will unfold. In order to plan for this uncertain future, managers have begun to use a tool known as scenario planning, in which climate models are used to identify different plausible climate conditions, known as "scenarios," for a particular area.

In a previous project, researchers with the North Central Climate Science Center worked with natural resource managers at Badlands National Park and on surrounding federal lands to model how different climate scenarios and management activities would impact the area's resources. The model that was developed answers critical "what if" questions regarding how management actions might affect focal resources, such as grazing lands, under different future climate conditions. Building on this work, researchers will produce management-relevant publications that translate the previous project's results into a format that can support management planning.

Using insights gained from the previous project, researchers will also design a process for integrating scenario planning and climate science into National Park Service (NPS) Resource Stewardship Strategies. These strategies are part of NPS's streamlined approach for guiding prioritization of a park's investments in resource stewardship. Researchers will work with Devils Tower National Monument in Wyoming as a case study for this integration effort.

Other NC CSC Activities

With the hosting agreement, the NC CSC supports and leads smaller in-house projects, activities and trainings, and administrative tasks, which help us to achieve our mission. 2017 activities have included:

Meetings/Workshops

National Climate Assessment (NCA) 4 Northern Great Plains Workshop

Staff from the NC CSC helped to plan and facilitate a Northern Great Plains NCA satellite meeting on February 22, 2017 at the USGS Fort Collins Science Center in Fort Collins.

Evapo-transpiration (ET) Workshop

Staff from the NC CSC planned and offered (including travel support) an evapo-transpiration workshop in Fort Collins on September 7-8, 2017. Invited participants included NC CSC staff, representatives from the FSAs, some project PIs, and other invited collaborators. The workshop was intended to provide an update of on-going research efforts to analyze potential (PET) and actual evapo-transpiration (ET) in the north central region of the US. The participants invited to the workshop were active in developing regional analyses of ET and PET to inform both the research and management communities.

All-CSC Meeting – Fairbanks, AK

Robin O'Malley (USGS Director), Aparna Bamzai (USGS Deputy Director), and Shannon McNeeley (CSU research scientist) attended the CSC-network all hands meeting in Fairbanks, AK on September 11-15, 2017. This annual meeting is meant to bring all of the USGS and University CSC-network staff together to discuss collaboration. McNeeley was selected to present a presentation on the Wind River Indian Reservation project during the meeting.

Research Coordination Meeting – FY17

NC CSC staff hosted a research coordination meeting on October 18-19, 2017 in Fort Collins. Representatives from funded projects came together for two days in order to discuss the newly funded projects, and to look for synergies between projects. This meeting also contributed to the kick-off of the NC CSC strategic planning process for 2018-2022.

Strategic Planning Workshop for the IPN

On November 6-8, 2017, the NC CSC hosted a strategic planning workshop for tribal and indigenous adaptation and capacity building (in conjunction with IPN leadership). The focus of the workshop was on where the IPN wants to go, and how they get there. The first day of the workshop was held in Fort Collins and the last two days were held in Boulder, CO, where workshop participants also met with Rising Voices staff.

Joint Retreat of NC CSC, Western Water Assessment, and USDA Northern Plains Climate Hub

The NC CSC, Western Water Assessment (WWA) and USDA Northern Plains Climate Hub (NPCH) met for a joint and collaborative retreat twice in 2017, on June 21-22, in the shortgrass steppe outside of Fort Collins, and on November 9, in Boulder, CO to set a collective vision and direction for future work. Attendees included staff from each of the organizations, as well as invited collaborators.

Partner Engagement

Connections within Colorado State University

Dennis Ojima (University Director) organized a climate change panel at the Natural Resource Ecology Laboratory's (NREL) 50th anniversary symposium on November 14, 2017. Ojima and Lackett were also invited to a Natural Resources Consortium workshop on December 7-8, 2017. This is a group that aims to integrate CSU Extension with groups across campus working on natural resource issues.

Tribal Engagement

Tribal engagement is one of the main mission areas of the NC CSC that does not always fit neatly into the projects/trainings described above. In addition to the inclusion of tribes in research projects and trainings where appropriate, NC CSC staff have also engaged with tribes through more informal, or "ad hoc" means. Examples are below:

- Strategic planning workshop for the IPN (see above-Miller)
- Webinar presentation – Applying Indigenuity: Native Communities Adapting to Weather Extremes and Climate Variability (Miller)
- Presentations and sessions at conferences for tribal/indigenous participants - AIHEC presentation, PRIMO conference, Rising Voices 5 poster and oral presentation (Miller and McNeeley)
- Connecting the IPN and USDA NE climate hub (Miller)
- Participation on cross-CSC advisory committee for BIA tribal liaisons (McNeeley)
- Presentation at Flathead Reservation in Montana for the Salish Kootenai Tribe climate adaptation efforts (McNeeley)
- Consultation for tribal partners with various tribes and other CSCs (McNeeley)
- Presentation to EPA Region 8 tribal committee about climate change (McNeeley)
- Engagement with Great Plains Tribal Water Alliance and Indian Nations Conservation Alliance (INCA) (McNeeley)
- Invited speaker at Northwest Tribal Climate Camp and Northwest Tribal Climate Summit (McNeeley)

Ad-hoc Activities (Unfunded)

In addition to the funded activities described above, NC CSC staff often field requests for invited presentations, workshop participation, consultations, instruction or training, or convening and coordination activities that fall outside of funded activities. There are also requests for service (i.e., manuscript review or serving on committees), student mentoring requests, and requests for product development or information. We call these activities ad-hoc activities. In 2017, NC CSC staff completed 64 such requested activities in the categories below (Figure 3).

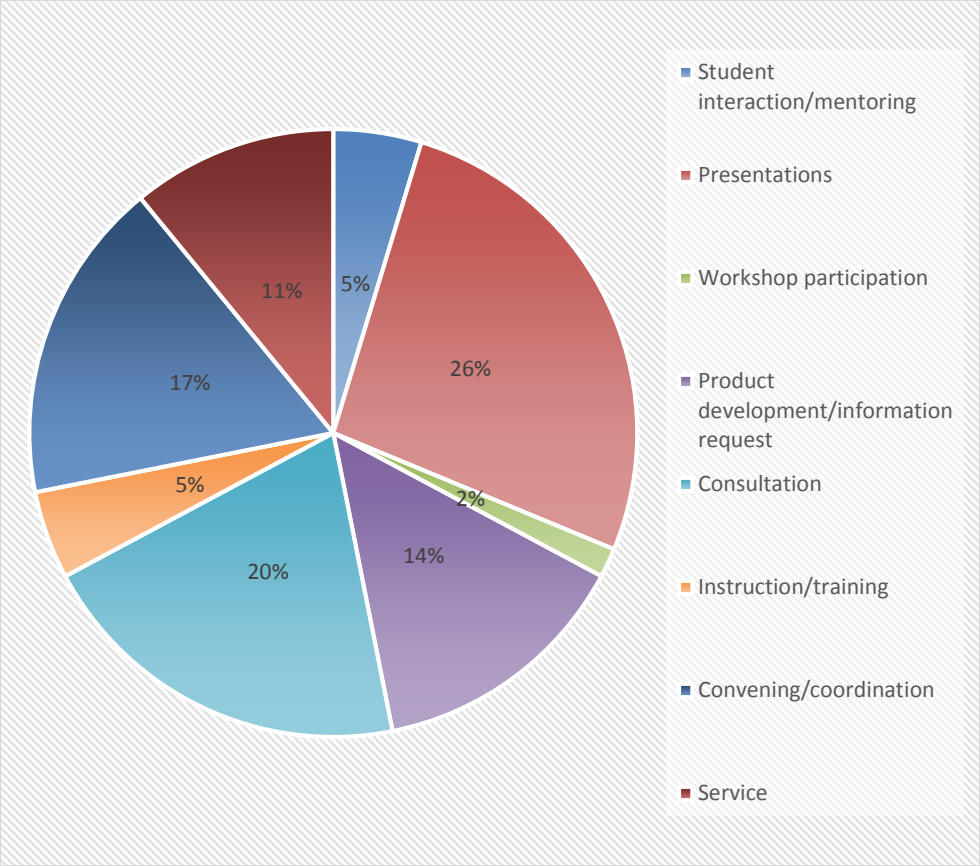

Figure 3: Breakdown of ad-hoc activities undertaken by NC CSC staff in 2017.

NC CSC Monthly Check-ins

The NC CSC holds monthly check-in webinars to feature a science presentation by one research team, and allow updates from all research projects for the shared benefit of all NC CSC and project personnel. A representative from each funded research project is required to be on the call each month.

Joint Steering Committee

In 2017, the Department of the Interior put a hold on CSC advisory committee meetings until an internal evaluation could be completed. As a result, there were no JSAC meetings during 2017, but the group will be revived and reorganized in 2018.

Congressional Outreach

In 2017, NC CSC staff have visited Washington DC twice for Congressional outreach, in coordination with University Directors from other CSCs in the network. Dennis Ojima (University Director) visited in March and Ojima and Jill Lackett (Deputy University Director) visited in November. During the November trip, the CSC directors also made visits to USGS, DOI, and OMB.

Communications

The NC CSC continues to employ a full-time communications specialist (Lindsey Middleton), although Jill Lackett also contributes to the Center's communication goals. Communications goals include, broadly, the translation of scientific information into various formats, identification of and outreach to target audiences, and a maintenance of communications venues and partners with whom to share resources

and disseminate information. In 2017, Middleton was responsible for website content and upkeep, newsletters, other news releases and press interaction, social media (Facebook and Twitter), and design and creation of printed informational and scientific products. In 2018, she (with input from other NC CSC staff) will finalize a strategic communications plan for the Center, update communications venues, and grow the NC CSC's communications network.

"Communications" can be a broad and complex term for the various interactions the NC CSC maintains and promotes. The subsections below specifically describe internal, sustained, staff-led efforts to translate and disseminate information from the NC CSC to specific audiences. It should be noted, however, that the NC CSC considers other aspects of its approach, like synthesis work and project communications with managers, to fall under the communications umbrella, as well. In addition to the below categories, NC CSC staff also work to improve science communication capacity and collaborate with project teams, other CSCs, regional research partners, and other groups on shorter-term science communication products.

Cross-Organizational Collaborations – blogs and news sites (ECCF, EcoPress, and CSU SOURCE)

One of the NC CSC's ongoing communications efforts involves using already-existing communications pathways, within local and national organizations, to build recognition and awareness of NC CSC science. In 2017, these efforts included working with the Early Career Climate Forum (ECCF) to both connect NC CSC early-career researchers with the ECCF and provide blogs to inform the early career climate research community. The NC CSC also partnered with its hosting department, the Natural Resource Ecology Laboratory, to contribute to a faculty-and-student-read science blog, EcoPress. Other connections include news stories in the CSU news outlets like SOURCE to reach university and regional audiences.

Quarterly NC CSC Newsletter

The NC CSC continued producing a quarterly newsletter in 2017, with the topic of the newsletter rotating between a focus on adaptation, climate drivers, ecological impacts, and capacity building. A new format will be introduced in 2018 to mail more frequent newsletters with regular sections. These will include staff and student highlights, a science story based on one of the NC CSC's projects, announcements (e.g., funding announcements, new collaborations/projects), new publications, and upcoming events. The newsletter audience includes research collaborators, regional science groups, and resource managers. The goal is to maintain connection and engagement with these partners by telling stories about current and relevant science, putting a face on the NC CSC, and presenting opportunities for interaction with the NC CSC.

Social Media

The NC CSC maintains Facebook and Twitter accounts. Organic growth led to Facebook followers increasing by 150% in 2017 (from about 100 to about 150 followers); efforts are ongoing to identify methods for reaching a larger percentage of the page's target audiences. These include early career researchers; members of agencies, universities, and other scientific and management organizations in the region; national partners; and other, more specified potential target audiences. The NC CSC posted stories about opportunities, science, and activities 76 times in 2017 (just over six times per month). The NC CSC Twitter page posted an average of six original tweets per month, with many more retweets and interactions, for an average of 3,080 "impressions" per month – impressions are the number of times a

post is viewed (including multiple views by one individual). A stronger effort to use photos and graphics in 2017 helped contribute to increased engagement on both of these platforms.

Website

The NC CSC worked in 2017 to more strongly comply with NCCWSC guidelines and connect NC CSC projects with NCCWSC project pages. Regularly updated and maintained content, including news, products, and events, were posted throughout the year. The NC CSC also held planning meetings and conducted research toward improving website structure and function; the results of this planning will be applied in coming months. In general, the NC CSC has identified managers and the layperson as primary target audiences and will make efforts to improve accessibility and translation for these audiences. A second consideration for the website will be its new primary goal of serving stories about the NC CSC and its science, management connections, and partnerships. Secondary goals and audiences will ensure that the website still reflects NCCWSC guidelines and serves resources for early career/students, science partners, and others.

Capacity Building

National Conservation Training Center (NCTC) Trainings

Two back-to-back NCTC trainings were held in Durango, CO on April 11 and 12-13, 2017. Brian Miller, NC CSC USGS research scientist, was an instructor for the one-day Climate Smart Conservation training held on April 11. Miller was also one of the coaches for the Climate Adaptation Workshop, hosted by the NC CSC, Mountain Studies Institute, and the Colorado National Heritage Program, held on April 12-13. This short course provided hands-on training for applying climate-smart principles to real natural resource management plans and projects that are local or regional in scope. The training and coaching session was based on the guide "Climate-Smart Conservation: Putting Adaptation Principles into Practice." Teams, consisting of two or more people, were coached using the climate-smart conservation framework and developed climate-informed conservation goals and integrated adaption planning into on-going work. Teams documented their project at the end of the workshop with a short summary.

Student and Early Career Training

During 2017, NC CSC actively contributed to the training of at least 29 graduate and undergraduate students, post-docs, and early career researchers:

NC CSC Staffing:

- Ashley Visocky (CSU, undergraduate student)
- Darin Schulte (CSU, post-doc)
- Trevor Even (CSU, graduate student)

FSA Adaptation project:

- Tyler Beeton (CSU, graduate student)

FSA Climate Drivers project:

- Candida Dewes (CU-Boulder, postdoc)
- William Radmacher (Front Range Community College, undergraduate student)

FSA Impacts project:

- Arjun Adhikari (MSU, postdoc)
- Katie Carroll (MSU, graduate student)
- Dave Laufenberg (MSU, graduate student)

White bark pine project:

- Tony Chang (MSU, graduate student)

- Katie Ireland (MSU, postdoc)

SW Colorado project:

- Katherine Clifford (CU-Boulder, graduate student)
- Patricia Orth (USGS, postdoc)

Sagebrush distribution project:

- Katie Renwick (MSU, postdoc)
- Jared Hoy (MSU, undergraduate student)

Wind River Indian Reservation project:

- Bree Drda (UNL, undergraduate student)

Land use switching project:

- Mary Doidge (MSU, graduate student)
- Yuyuan Che (MSU, graduate student)

Species of conservation concern project:

- Adam Wilke (USGS, postdoc)

NPS Resource Stewardship Strategy project:

- Amber Childress (CSU, graduate student) – leveraged funding

NSF GRIP (Graduate Research Internship Program) intern (leveraged funding):

- Deidre Jaeger (CU-Boulder, graduate student)

CEMML project (leveraged funding):

- Shelley Spear (CSU, graduate student)
- Jennifer Timmer (CSU, graduate student)
- Shawna Zimmerman (CSU, graduate student)
- Alannah Liebert (CSU, undergraduate student)
- Matt Willli (CSU, undergraduate student)
- MaKenzie Ruppert (CSU, undergraduate student)

SUPER (Skills for Undergraduate Participation in Ecological Research) students (leveraged funding):

- Valeria Cintora (CSU, undergraduate student)
- Jesse Stahl (CSU, undergraduate student)

See also ad-hoc activities (above).

Modeling/Computing Activities

Bob Flynn (GIS/data management specialist)

In the Climate Primers project, Flynn and Hilinski developed a library of scripts in R programming language for modeling climate change in defined regions. This involves extracting both historical and future projected data and presenting this data in a report composed of narratives, data tables, graphs and maps. The data includes temperature, precipitation, growing degree days, and extreme day counts (hot, cold, wet, etc.). The developed software allows for selecting a range of historical and projected years and for selecting an area for analysis defined by GIS shape files.

ClimatePrimers 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.

Flynn provided GIS support for the NCCSC in various project areas including administrative, Foundational Science Areas, and funded projects. The work involves developing presentation maps, performing spatial analysis, and maintaining a spatial data library. It also includes support work on the NC CSC webpage for our on-line map tool, which allows for viewing and analyzing a variety of spatial data within our region.

Darin Schulte (post-doc)

- Processing of DAYCENT and SSEBop data for model comparison
  - The aim was to compare SSEBop (remotely sensed data) evapotranspiration estimates with those from the DAYCENT (ecophysiological model) for approximately 450 US counties in the central / western US. Processing required spatial and temporal aggregations to enable model comparison due to the inherently different space and time structures for the respective models.
- Construction of interactive web application for multiple ET model comparisons
  - SSEBop and DAYCENT comparisons resulted in numerous figures and charts for each county being considered. This made it challenging to efficiently view results and understand similarities and differences between model predictions. We developed a proof-of-concept web application via the R Shiny package to facilitate interactive data visualizations.
- Construction of interactive web applications for Climate Primers data sets
  - Building on the concept of interactive web applications for data visualization, we have begun creating a template web app for visualizing Climate Primers data sets. This work uses the SSEBop / DAYCENT Shiny app as a base and incorporates additional functionality specific to Primers data sets.
- Development of proof-of-concept, standalone web application using Google Earth Engine
  - Further expanding on the use of web applications for interactive data visualization, we have developed several stand-alone web applications that utilize the processing power and data storage capabilities of Google Earth Engine.
- Processing of 8-day MODIS NDVI dataset from Oak Ridge National Laboratory (ORNL)
  - Several NDVI data sets are being used as independent data sets to evaluate results from two grassland productivity models (DAYCENT and GRASSCAST). The 8-day MODIS NDVI dataset from ORNL was chosen due to its fine-scale temporal resolution. The dataset consists of 16 years of approximately weekly data for the contiguous US. Data processing involved the creation of custom R code for batch processing these relatively large data sets, and involved runs on local computers, as well as the RUBEL computing cluster.
- Analysis of DAYCENT / SSEBop data for the Shortgrass Steppe CPER
  - In preparation for an Evapotranspiration Workshop hosted by NC CSC, we analyzed model results for ET at a specific site in Northern Colorado and presented the comparison at the workshop.

Tom Hilinski (programmer, high output computing)

DaymetLOCA was used for analysis and projections of U.S. Air Force bases in regards to potential ecosystem changes due to changes in climate. DaymetLOCA is a synthetic future climate dataset that is generated for specific sites. The data is on an approximately 1 km latitude-longitude grid matching Daymet resolution, and is derived from historical Daymet data and LOCA future data. An R package provides the functionality to generate the DaymetLOCA data.

Administration

Five-year External Review

The NC CSC underwent a five-year external review on January 31-February 2, 2017. Over the three days, the science review team met with NC CSC staff, NCUC members, PIs and science producers and users in Fort Collins, to review the progress made by the Center in the first-phase and to make suggestions for improvements. The report from the review team can be found here: https://nccwsc.usgs.gov/sites/default/files/files/NCCSC%20Review%20Report%20Final%20Draft%207-17-17.pdf

Preparation of Rebid Proposal to Host the NC CSC

NC CSC university staff responded to the request for proposals to host the NC CSC by submitting a rebid proposal to NCCWSC in September 2017. The preparation of the proposal involved many meetings and phone calls with PIs, partners and university consortium members to develop the ideas in the proposal.

Project Management and Reporting

PDASH is still being used for project management and reporting. Automated reminders get sent to funded PIs when reports are due or as reminders to fill out the monthly Google form, which we have instituted in 2017 so each project can easily report on monthly activities, needs, and synergies before each monthly webinar. We are also collecting highlights from NC CSC staff on another Google form to report to NCCWSC on a weekly basis.

NC CSC staff climate-related Publications

- Krawchuk, M. A., Haire, S.L., Coop, J., Parisien, M.A., Whitman, E., Chong, G., Miller, C., (2016). "Topographic and fire weather controls of fire refugia in forested ecosystems of northwestern North America." *Ecosphere*, *7*(12). DOI: 10.1002/ecs2.1632.
- Chen, M., Parton, W.J., Del Grosso, S.J., Hartman, M.D., Day, K.A., Tucker, C.J., Derner, J.D., Knapp, A.K., Smith, W.K., Ojima, D.S., Gao, W. (2017). "The signature of sea surface temperature anomalies on the dynamics of semiarid grassland productivity." *Ecosphere 8*(12) DOI: 10.1002/ecs2.2069.
- Senay, G.B., Schauer, M., Friedrichs, M., Velpuri, N.M, Singh, R.K. (2017). "Satellite-based water use dynamics using historical Landsat data (1984–2014) in the southwestern United States". *Remote Sensing of Environment*, *202*. 98-112. DOI:10.1016/j.rse.2017.05.005.
- Velpuri, N. M., **Senay, G. B**., (2017). "Partitioning evapotranspiration into green and blue water sources in the conterminous United States". *Scientific Reports*, *7*(1), 6191.
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- Reitz, M., **Senay, G. B.**, Sanford, W. E. (2017). "Combining remote sensing and water-balance evapotranspiration estimates for the conterminous United States". *Remote Sensing*, *9*(12), 1181.
- Alemayehu, T., Griensven, A. V., **Senay, G. B**., Bauwens, W. (2017). "Evapotranspiration mapping in a heterogeneous landscape using remote sensing and global weather datasets: Application to the Mara Basin, East Africa." *Remote Sensing*, *9*.390.
- Sofaer, H.R., Barsugli, J.J., Jarnevich, C.S., Abatzoglou, J.T., Talbert, M.K., Miller, B.W., Morisette, J.T. (2017). "Designing ecological climate change impact assessments to reflect key climatic drivers." *Global Change Biology*, *23*(7). 2537-2553.
- 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.

North Central Climate Science Center on the web:
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Appendices

Publications

Climate FSA (Rangwala and Dewes)

- Dewes C., Rangwala, I., Hobbins, M., Barsugli J., Kumar, S. (2017). "Drought risk assessment under climate change is sensitive to methodological choices for the estimation of evaporative demand." *PLOS ONE*, *12*(3). DOI:10.1371/journal.pone.0174045
- Hobbins, M.T., Barsugli, J.J., Dewes, C.F., Rangwala, I. (2017). Monthly Pan Evaporation Data across the Continental United States between 1950-2001. *United States Geological Survey*. https://doi.org/10.21429/C9MW25
- Lukas, J., Hobbins, M., Rangwala I., and the EDDI team (2017). *The EDDI User Guide*, *1*. https://esrl.noaa.gov/psd/eddi/pdf/EDDI_UserGuide_v1.0.pdf
- McNeeley S.M., Dewes, C., Stiles, C.J., Beeton, T., Rangwala, I., Hobbins, M., Knutson, C. (2017). "Anatomy of an interrupted irrigation season: Micro-drought at the Wind River Indian Reservation." *Climate Risk Management*. https://doi.org/10.1016/j.crm.2017.09.004
- Rondeau, R., Neely, B., Bidwell, M., Rangwala, I., Yung, L., Clifford, K., Schultz, T., (2017), "Spruce-fir landscape: Upper Gunnison River Basin, Colorado. Social-ecological climate resilience project." Report prepared for the *North Central Climate Science Center*, 55. http://www.cnhp.colostate.edu/download/documents/2017/SECR_Spruce-Fir_Landscape_Report_4-30-2017_Final_with_Appendices.pdf
- Rondeau, R., Neely, B., Bidwell, M., Rangwala, I., Yung, L., Clifford, K., Schultz, T. (2017), "Sagebrush landscape: Upper Gunnison River Basin, Colorado: Social-ecological climate resilience project." Report prepared for the *North Central Climate Science Center*, 56. http://www.cnhp.colostate.edu/download/documents/2017/SECR_Sagebrush_Landscape_Report_4-30-2017_Final_and_Appendices.pdf

Impacts FSA (Hansen and Adhikari)

- Hansen A.J., Adhikari, A., Rangwala, I. (Manuscript in review). "Ecological water stress under projected climate change across the hydroclimate gradients in north central United States: A comparison of two potential evapotranspiration methodologies." *Ecosystems.*
- Adhikari, A., and Hansen, A.J. (In review). "Land use change around the wildland ecosystems of the North Central United States." *Landscape and Urban Planning*.
- Hansen, A.J., Phillips, L., Tabor, G., Olliff, S.T., Watson, J., Groves, C., Gross, J., Goetz, S., Theobald, D. (Submission Dec 2016). "A call for better sustaining Yellowstone and America's other wildlands." *BioScience.* Previously submitted and now under revision.

Adaptation FSA (Ojima and McNeeley)

- Averyt, K., Derner, J.D., Dilling, L., Guerrero, R., Joyce, L., McNeeley, S., McNie, E., Travis, W., (2017). "Regional Climate Response Collaboratives: Multi-institutional support for climate resilience." *Bulletin of the American Meteorological Society*. DOI: 10.1175/BAMS-D-17-0183.1
- Beeton, T.A., McNeeley, S.M., Miller, B.W., Ojima, D. "Grounding simulation models with qualitative case studies: Toward a holistic approach to make climate science usable for US public land management." *Climate Risk Management.* In 2nd Review.
- McNeeley, S.M. (2017). "Sustainable climate change adaptation in Indian Country." *Weather, Climate, and Society, 9*, 393–404. DOI: 10.1175/WCAS-D-16-0121.1

- McNeeley, S.M., Beeton, T.A. (2017). "Wind River Reservation: Drought risk and adaptation in the interior (DRAI) report." *North Central Climate Science Center*, Fort Collins, CO. http://nccsc.colostate.edu/sites/default/files/projects/McNeeley_%26_Beeton_2017.pdf
- McNeeley, S.M., Dewes, C., Stiles, C., Beeton, T.A., Rangwala, I., Hobbins, M., Knutson, C. (2017). "Anatomy of an interrupted irrigation season: Micro-drought at the Wind River Indian Reservation." *Climate Risk Management.* DOI: 10.1016/j.crm.2017.09.004
- McNeeley, S.M., Even, T.L., Gioia, J.B., Knapp, C.N., Beeton, T.A. (2017). "Expanding vulnerability assessment for public lands: The social complement to ecological approaches." *Climate Risk Management*, *16*, 106–119. DOI: 10.1016/j.crm.2017.01.005

Southwest Colorado Project (Burkardt and Schuster)

- Burkardt, N. Orth, P.B., Yung, L., Wyborn, C., Clifford, K. (In preparation) "Barriers to developing and implementing climate change adaptation strategies in natural resource management agencies" (journal article).
- Rondeau, R., Neely, B., Bidwell, M., Rangwala, I., Yung, L., Clifford, K., Schulz, T. (2017) "Sagebrush landscape: Upper Gunnison River Basin, Colorado." *Social-Ecological Climate Resilience Project.* North Central Climate Science Center, Ft. Collins, Colorado. Report prepared with the Gunnison Climate Working Group and Stakeholders in Gunnison, Colorado.
- Rondeau, R., Neely, B., Bidwell, M., Rangwala, I., Yung, L., Clifford, K., Schulz, T. (2017) "Spruce-Fir landscape: Upper Gunnison River Basin, Colorado." *Social-Ecological Climate Resilience Project*. North Central Climate Science Center, Ft. Collins, Colorado. Report prepared with the Gunnison Climate Working Group and Stakeholders in Gunnison, Colorado.
- Rondeau, R., Neely, B., Bidwell, M., Rangwala, I, Yung, K.L., Clifford, K. (2017) "Pinyon-Juniper landscape: Upper San Juan River Basin, Colorado." *Social-Ecological Climate Resilience Project.* North Central Climate Science Center, Ft. Collins, Colorado.
- Rondeau, R., Neely, B., Bidwell, M., Rangwala, I., Yung, K.L., Clifford, K. (Drafted and submitted for review, 2017) "Seeps, springs and wetlands: Upper San Juan River Basin, Colorado." *Social-Ecological Climate Resilience Project.* North Central Climate Science Center, Ft. Collins, Colorado.
- Wyborn, C. and Yung, L. (In preparation). "Knowledge politics of adaptation: engaging with uncertainty in public land management." (journal article)

Surrogate Species Project (Skagen and Noon)

- Reese, G.C., Rashford, B.S. *In review.* "Projected likelihood of grassland conversion to cropland in the U.S. Northern Plains and Prairies given climate change". *Open File Report, US Geological Survey.*
- Skagen, S.K., Steen, V.A., Sofaer, H.R., Noon, B.R. *In preparation.* "Management insights for wetland birds exposed to rapid climate change."
- Sofaer, H.R., Barsugli, J.J, Jarnevich, C.S., Abatzoglou, J.T., Talbert, M.K., Miller, B.W., and Morisette, J.T. (2017). "Designing ecological climate change impact assessments to reflect key climatic drivers." *Global Change Biology* DOI: 10.1111/gcb.13653
- Sofaer H.R., Flather, C.H., Noon, B.R., Skagen, S.K., and Steen, V.A. *In review.* "Clustering and ensembling approaches to support surrogate-based species management". *Ecography.*
- Steen V.A., Ray, A.R., Skagen, S.K., Sofaer, H.R., Noon, B.R. (2017). "Projecting species vulnerability to climate change: which uncertainty sources matter most and extrapolate best?" *Ecology and Evolution*. DOI: 10.1002/ece3.3403

- Steen V.A., Skagen, S.K., Noon, B.R. *In review*. "Preparing for an uncertain future: assessing responses of migrating shorebirds to historic climatic fluctuations in the Prairie Pothole Region." *Ecosphere*.

Wind River Project (Knutson)

- McNeeley S.M., Dewes, C., Stiles, C.J., Beeton, T., Rangwala, I., Hobbins, M., Knutson, C. (2017). "Anatomy of an interrupted irrigation season: Micro-drought at the Wind River Indian Reservation." *Climate Risk Management*. DOI: 10.1016/j.crm.2017.09.004
- McNeeley, S.M. (2017). "Sustainable climate change adaptation in Indian Country." *Weather, Climate, and Society*, *9*, 393–404. DOI: 10.1175/WCAS-D-16-0121.1

Scenario Planning Project (Symstad)

- Friedman, J.M., and Griffin, E.R. (2017). "Management of plains cottonwood at Theodore Roosevelt National Park, North Dakota: Fort Collins, Colo." *National Park Service Natural Resource Report.* NPS/THRO/NRR—2017/1395, 31.
- Friedman, J.M., Ankney, F.R., and Wolf, M. (2017). *In review*. "Age and growth of cottonwood trees along the Missouri River: Prairie Naturalist."
- Griffin, E.R., and Friedman, J.M. (2017). "Decreased runoff response to precipitation, Little Missouri River Basin, northern Great Plains, USA." *Journal of the American Water Resources Association*, *53*(3), 576–592. DOI: 10.1111/1752-1688.12517.
- Miller, B.W., Schuurman, G.W., Symstad, A.J., and Fisichelli, N.A. (2017). *In preparation.* "Embracing complexity and uncertainty: Merging qualitative and quantitative tools to inform natural areas management under climate change." *Park Science*.
- Miller, B.W., Symstad, A.J., Frid, L., Fisichelli, N.A. and Schuurman, G.W. (2017). "Co-producing simulation models to inform resource management: a case study from southwest South Dakota." *Ecosphere*, *8*(12).
- Symstad, A.J., Fisichelli, N.A., Miller, B.W., Rowland, E. and Schuurman, G.W. (2017) "Multiple methods for multiple futures: Integrating qualitative scenario planning and quantitative simulation modeling for natural resource decision making." *Climate Risk Management*, *17*, 78–91. DOI:10.1016/j.crm.2017.07.002.

Land Use Switching Project (Wolter, formerly Hennessey)

- Arora, G. and Wolter, P. Tracking land cover change along the western edge of the U.S. Corn Belt from 1984 through 2016 using satellite sensor data: Observed trends and contributing factors. *Revised and resubmitted to journal in Feb 2018*.
- Arora, G. and Wolter, P. Characterizing Dakotas' land use changes using historical satellite sensor data: 1984-2014. Submitted to *Landscape Ecology*.
- Arora, G., Feng, H., Hennessy, D., Anderson, C. In preparation: Evidence of differential weather impacts on regional crop yields and land use change."
- Miao, R., Feng, H., Hennessy, D.A. (2017) "Grassland easement evaluation and acquisition: An integrated framework*."* Paper submitted to *Journal of Environmental Economics and Management*.
- Wang, T., Luri, M., Janssen, L., Hennessy, D.A., Feng, H., Wimberly, M.C., Arora, G. (2017). "Determinants of motives for land use decisions at the margins of the Corn Belt." *Ecological Economics, 134*. 227–237.

- Wimberly, M., Janssen, L., Hennessy, D., Luri, M., Chowdhury, N., Feng, H. (2017). "Cropland expansion and grassland loss in the eastern Dakotas: New insights from a farm-level survey." *Land Use Policy, 63.* 160-173.

Capacity Building Project (Ojima)

- Richardson, A. D., Weltzin, J.F., Morisette, J.T. (2017) "Cross-scale phenological data integration to benefit resource management and monitoring." *Eos, 98,* DOI: 10.1029/2017EO065709.

Presentations and Outreach

Climate FSA (Rangwala and Dewes)

- Rangwala, I., Dewes, C. (2017). Hydroclimate analysis for the Wind River Indian Reservation as relevant to water resources and impacts from climate extremes. *Wind River Indian Reservation Drought Preparedness Project - Final Workshop, Ft. Washakie, WY.* Nov 14.
- Rangwala, I., Dewes, C., Hobbins, M., Barsugli, J., (2017). PET Discussions. *NCCSC Evapotranspiration Workshop*, *Ft. Collins, CO.* Sep 7-8.
- Lyon N.J., D. M. Debinski, and I. Rangwala (2017). Species distribution modeling to predict prairie restoration success under climate change. *Ecological Society of America Annual Meeting, Portland, OR. Aug 7.* https://eco.confex.com/eco/2017/webprogram/Paper64752.html
- Rangwala, I., M. Hobbins and J. Lukas (2017). Evaporative Demand Drought Index (EDDI): Tracking the "atmospheric demand" side of drought for monitoring and early warning. *Western Water Assessment/NIDIS Webinar.* May 11. https://cirescolorado.adobeconnect.com/_a1166535166/p1l4r3ibhbe/
- Dewes, C.F., Rangwala, I., Fish, T.W. (2017) Recent trends in snow and rain in Wyoming's Wind River Area. *15th Climate Prediction Applications Science Workshop, Anchorage, AK.* May 2-4. https://accap.uaf.edu/sites/default/files/20170428_cpaswprogram_web_0.pdf
- Dewes, C.F., Rangwala, I., Hobbins, M.T., Barsugli, J.J., (2017) Assessing drought risk under climate change in the US Great Plains via evaporative demand from downscaled GCM projections. *15th Climate Prediction Applications Science Workshop, Anchorage, AK.* May 2-4.
- Rangwala, I. (2017). Developing "actionable" climate change scenarios for "a more" robust decision making process: Examples from the Intermountain West. *Utah State University's Spring Runoff Conference*. Mar 29. http://water.usu.edu/conference/2017/index
- Rangwala, I., Senay, G. (2017). Monitoring the exchange of moisture between the land and atmosphere to improve our understanding of drought. *NCCWSC Ecological Drought webinar series presentation.* Mar 21. https://nccwsc.usgs.gov/webinar/DroughtSenayRangwala
- Rangwala, I., Rondeau, R. (2017). Developing scenarios for the landscape-scale. *Social-Ecological Resilience and Changing Landscapes Webinar Series.* Feb 8. https://www.fs.fed.us/rmrs/social-ecological-resilience-and-changinglandscapes-webinar-series
- Rangwala, I. (2017). NCCSC's Climate Foundational Science Area. Webinar presented to the review committee of the NCCSC 5-year review. Jan 25.
- Rangwala, I. (2017). Development and use of climate scenarios for natural resource management in southwestern Colorado. *Lecture to graduate course @ Masters in Environmental Management at Western State Colorado University, Gunnison, CO.* Jan 27.

Adaptation FSA (Ojima and McNeeley)

- Beeton, T.A., McNeeley, S., Miller, B., Ojima, D. (2017). Making climate science usable on the ground: the integration of local knowledge with simulation models for bison management in a

complex and changing world. *Meeting of the Society for Applied Anthropology, Santa Fe, NM, March 27-April 2.*

- Beeton, T.A. (2017). A student perspective of how NCCSC has increased my understanding of applying integrated social-ecological systems approaches to natural resource management contexts. *Invited presentation to the DOI North Central Climate Science Center Review Committee.*
- Lackett, J. M. Ojima, D. (2017). "One Size Does Not Fit All: The need for multidisciplinary, cross-sectoral climate adaptation training for diverse audiences." *National Adaptation Forum, St. Paul, MN.* May 11.
- McNeeley invited to present and participate in drought and flood planning workshop at Flathead Reservation in Montana for the Salish and Kootenai Tribe climate adaptation efforts (1/15/17)
- McNeeley invited by Bets McNie to give a seminar to her class at UC Boulder on social capital (3/6/2017)
- McNeeley Invited to speak to EPA Region 8 tribal committee in Denver about climate change (3/17/2017)
- McNeeley invited to present to Rising Voices conference in Boulder about the National Climate Assessment and the CSC tribal liaisons (4/15/17)
- Ojima, D. S., Lackett, J. M., McNeeley, S. (2017). Building partnerships to produce actionable science to support climate-informed management decisions: North Central Climate Science Center Example. *American Geophysical Union, New Orleans, LA*. Dec 13.

Southwest Colorado Project (Burkardt and Schuster)

- Social-Ecological Resilience and Changing Landscapes Webinar Series. Laurie Yung planned a webinar series to share project results and lessons learned. The series, ***The Social-Ecological Resilience and Changing Landscapes Webinar Series*** explored activities and tools that facilitate effective adaptation and build social-ecological resilience in the context of changing landscapes. The six webinars were presented from January to March 2017, and included presentations by members of the project team. This webinar series was sponsored by the U.S. Forest Service Rocky Mountain Research Station, North Central Climate Science Center, University of Montana W.A. Franke College of Forestry and Conservation, United States Geological Survey, The Nature Conservancy, Mountain Studies Institute, Colorado Natural Heritage Program, Western Water Assessment, University of Colorado, and NOAA. Broadcasts can be found at: https://www.fs.fed.us/rmrs/social-ecological-resilience-and-changing-landscapes-webinar-series. The titles and presenters of the webinars are listed below:
    - Conducting Vulnerability Assessments: *Renee Rondeau (Colorado Natural Heritage Program) and Marcie Bidwell (Mountain Studies Institute)*
    - Developing Scenarios for the Landscape-Scale: *Imtiaz Rangwala (Western Water Assessment) and Renee Rondeau (Colorado Natural Heritage Program)*
    - Understanding the Views of Decision-Makers: *Laurie Yung (University of Montana) and Katie Clifford (University of Colorado)*
    - Building Social-Ecological Response Models: *Rudy Schuster (United States Geological Survey)*
    - Engaging Stakeholders in Developing Adaptation Strategies: *Marcie Bidwell (Mountain Studies Institute) and Betsy Neely (The Nature Conservancy)*
    - Connecting Insights to Policy-Making and the Institutional Context: *Nina Burkardt (United States Geological Survey) and Laurie Yung (University of Montana)*

- Neely, B., Rondeau, R., Bidwell, M., Burkardt, N., Schuster, R., Rangwala, I., Yung, L., Schulz, T. (2017). "Engaging Stakeholders in Developing Social-Ecological Adaptation Strategies in Southwestern Colorado." Poster at the *National Adaptation Forum, St. Paul, MN.*

Surrogate Species Project (Skagen and Noon)

- Skagen, Steen, Sofaer, Noon, Reese, and Rashford. (2017). "Plains and Prairie Pothole Landscape Conservation Cooperative." *Webinar.*

Wind River Project (Knutson)

- Knutson, C. (2017) Vulnerability Assessment Introduction with Case Studies. *Lower Missouri River Basin Drought Early Warning Workshop, Nebraska City, NE.* Mar 8.

Scenario Planning Project (Symstad)

- Miller, B.W., Morisette, J.T. (2017). State-and-transition simulation modeling: A tool for assessing the interacting effects of climate, ecological processes, and management on wildlife habitat. *The Colorado Chapter of the Wildlife Society Annual Meeting*, *Fort Collins, CO.*
- Miller, B.W., and Morisette, J.T. (2017). Simulating the effects of climate change and resource management on ecosystems: Case studies from forest and rangeland systems using state-and-transition simulation modeling. *13th Biennial Scientific Conference of the Greater Yellowstone Ecosystem, Jackson, WY.*
- Symstad, A.J., Miller, B.W., Frid, Leonardo, Fisichelli, N.A., Schuurman, G.W. (2017) Range management and climate adaptation: Quantitatively deciding how to let the chips fall. *Society for Range Management, St. George, UT.*
- Symstad, A.J., Miller, B.W., Frid, Leonardo, Fisichelli, N.A., and Schuurman, G.W. (2017). A model for exploring grassland management in alternative climate scenarios. *Black Hills Area Botany and Ecology Workshop, Rapid City, SD.*
- Symstad, A.J. (2017) Ecological science for climate change planning: Examples from the Black Hills and Northern Great Plains. *To the Norbeck Society, a Black Hills (S. Dakota/WY) area public lands citizens group.* Apr 13.

Land Use Switching Project (Wolter, formerly Hennessey)

- Arora, G., Hennessy, D.A., Feng, H., Wolter, P.T. (2017) "Conservation easement acquisitions amidst localized spillover effects in grassland conversions: Analysis using remotely-sensed data." Econometrics Track Session paper presented at *AAEA Annual Meeting, Chicago, IL.* July 31-August 1.
- Doidge, M.*, Feng, H., Hennessy, D.A. (2017) "A test of the gambler's and hot hand fallacies in farmers' weather and market predictions." Poster presented *at 2017 Conference on Behavioral & Experimental Agri-Environmental Research: Methodological Advancements & Applications to Policy (CBEAR-MAAP), Shepherdstown, WV*. Oct 14-15.
- Miao, R.*,Feng, H., Hennessy, D.A. (2017) "Grassland easement evaluation and acquisition: A stochastic dynamic perspective." Selected paper presented at the *Association of Environmental and Resource Economists (AERE) Annual Summer Conference in Pittsburgh, PA, May 31-June 2.*
- Doidge, M.*, Feng, H., Hennessy, D.A. (2017) "Potential role of regret in farmers' land conversion decisions." Poster Presented at the 2017 *Agricultural and Applied Economics Association (AAEA) Annual Meeting, Chicago IL.* July 31.
- Doidge, M.*, Feng, H., Hennessy, D.A. "Farmers' revenue conditions predictions and land conversion decisions: evidence of the gambler's fallacy." Selected paper presentation

at *AAEA Annual Meeting, Chicago, IL.* July 30-Aug. 1. Also presented at the 2017 *Southern Ontario Behavioural Decision Research Conference, Kingston, ON*. May 12.

- Doidge, M., Feng, H., Hennessy, D.A. (2017) "Farmers' motivations for land conversion in the prairie pothole region of North and South Dakota." Oral presentation at the *4th Biennial America's Grasslands Conference: United for Conservation, Fort Worth, Texas*.
- Doidge, M.* "A behavioral approach to land use changes in North and South Dakota." Presented at the *2016 Climate, Food, Energy and Water Climate Change Symposium.* Nov 8.
- Doidge, M., Feng, H., Hennessy, D.A., "Assessing land conversion in the U.S. prairie pothole region with farm level data: How important are economic returns and conversion costs?"

Capacity Building Project (Ojima)

- Miller, B.W., Davíd-Chavez, D.M., Elevitch, C., Hamilton, A., Hatfield, S.C., Jones, K.D., Rabin, R., Rosemartin, A., Souza, M.K., Sparrow, E., and Members of the Indigenous Phenology Network. (2017). "The Indigenous Phenology Network: Engage, Observe, and Adapt to Change". Poster at *American Geophysical Union, New Orleans, LA.* December.
- Miller, B., Souza, K., Elevitch, C. (2017). Growing the Indigenous phenology network. *Pacific Risk Management Ohana annual meeting, Honolulu, HI*.
- Miller, B., Souza, K., Elevitch, C. (2017) Growing the Indigenous phenology network. *American Indian Higher Education Consortium conference, Rapid City, SD.*
- Souza, K., Elevitch, C., Miller, B.W., et al. (2017). "VICTree Gardens." Poster at *Rising Voices V*, *Boulder, CO*. April.
- Souza, K., Purgus, S., Elevitch, C., Gough, B., Miller, B. (2017). Applying Indigenuity: Native communities adapting to weather extremes and climate variability. *BIA Applying Indigenuity Webinar Series.* March 15.