Research Proposal:
Forecasting Climate Change Impacts on Conifer Forests of the Intermountain West

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Mountain forests are important ecosystems within the USA's Intermountain West. They contain more biomass than other regional ecosystems and grow in mid-to-high elevation locations that receive the majority of the region's yearly water input. Most of this annual water input accumulates in winter as a persistent snowpack that is later released in a relatively short spring melt event. There is growing evidence that climate change will have significant effects on regional snow accumulation and this annual melt event. These changes are likely to be of great significance to both the forests of the Intermountain West and to human settlements that depend on these forests for water, recreation, and wildlife [1, 2].

Two aspects of climate change are anticipated to lead to a shorter duration of the snow-covered season and a faster rate of snowmelt in coming decades. First, rising mean temperatures associated with climate change will decrease the duration of the snow-covered season and increase the proportion of precipitation that falls as rain instead of snow. Second, dust deposition on snow is likely to increase. Dust on the snow surface lowers the reflectivity of the snowpack, and the change in surface energy balance accelerates the melt cycle of the snowpack [3]. A number of studies suggest that earlier melt will become increasingly important to the ecosystems of the Intermountain West as the basins of the region become increasingly arid and dusty [1, 2, 4]. Each of the above scenarios decreases the duration of the snowpack and influences the rate of snowmelt, but they each have fundamentally different effects on the seasonal temperature and moisture regimes in soils. Both scenarios, and their associated impacts on the forests and soils of the Intermountain West, are in need of scientific investigation.

Our research is centered on the question "How will climate change influence conifer forest distributions and carbon cycling in the Intermountain West?" Our objective is to provide a predictive basis for understanding how climate change will impact the functioning, distribution, and carbon stocks of conifer forests in the region. We currently have a grant proposal in review at the National Science Foundation (the full proposal is available upon request) that proposes a suite of experiments examining the potential impacts of global change on the forests of the Intermountain West.

Our objective will be accomplished with a three-year study, using a combination of observational and manipulative field experiments combined with modeling and synthesis. Below, we propose 1) experiments in three conifer forests spanning an elevation gradient in Big Cottonwood Canyon, and 2) a general survey of forests across a climate gradient in the Wasatch and Uinta Mountains. These experiments and associated monitoring activities will generate data, modeling products and an intellectual framework for understanding the hydrologic and ecosystem processes of Big Cottonwood Canyon and similar regions of the Intermountain West region. Project results and data will be made freely available to anyone interested including land and water managers, public entities, and scientists.

Details of proposed research project:

Our scientific goals require investigation of forest processes across an elevation gradient and across forests that vary significantly in their present climate (temperature and precipitation). Hence this effort will require us to conduct scientific research at a wide variety of locations on both public and private land. We have discussed this project in a June 2008 preliminary meeting with Forest Service staff (see letter of support from B. Ferebee). We have also been in contact with the relevant private landowners and the Watershed Management office of Salt Lake City Public Utilities, and they have offered their preliminary support for our research activities in Big Cottonwood Canyon. We request permission to conduct research of two types varying in intensity, study forests and survey forests.

Study forests (3 total forests, 1 each at low, middle, and high elevation in Big Cottonwood Canyon). These forests will be our primary focus and will be studied intensively for 3 or more years. We have selected preferred and alternate low, middle, and high elevation sites (see Attachment 1). Criteria for selection included

- Relatively undisturbed, south-facing conifer stands of white fir, Douglas-fir, or subalpine fir spanning the maximum elevation range possible
- Relatively distant from popular winter and summer trailheads, cabins, ski resorts, etc.
- Proximity to Salt Lake City, and location within a single canyon, to facilitate frequent research visits

Equipment and measurements: At each site we will install a small, solar-powered weather station (10 ft tall mast) for continuous measurement of weather, soil moisture and temperature, and tree sap flow (water use). These will be temporary stations, installed without concrete foundations, for a total of 3 or more years. Each of these stations will contain dataloggers that will automatically record data from these sensors.

In addition to the automated measurements, we will install a few temporary measurement devices and make manual measurements at regular intervals throughout the year. Litterbags and root ingrowth cores will be deployed and collected at seasonal intervals for assessment of decomposition rates and belowground carbon allocation. PVC soil collars will be installed for the measurement of soil respiration in summer and winter. Surface traps will be used to quantify litterfall (needles falling to the ground). Several other sample collection and measurement activities will occur periodically, including needle, branch, and increment core sampling, plant pre-dawn water potential and leaf area measurements. Measurement and sampling details are summarized in Attachment 2. These installations and manual measurements will take place in, or adjacent to six replicate experimental plots (8 meter circles, three treatment and three control plots) that we will delineate at each forest site. All of these measurements are harmless to the trees.

Experimental manipulations: At each site, we will accelerate the rate of the spring snowmelt cycle by 4-6 weeks on 3 of the experimental plots in each forest. To accomplish this we will use a portable DC leaf blower to apply a thin layer of sand to the surface of the snowpack. Sand treatments will be applied weekly during the spring snowmelt cycle, or more often as needed when snowfall events cover the sand. We will apply these treatments in the springs of 2010, 2011, and 2012. The remaining 3 untreated plots will serve as a control. The red sand that will be applied is derived from the

Chinle/Moenkopi formations of southern Utah. The sand has a low spectral albedo and extremely low nutrient content [5]. The sand will be applied weekly at a rate of 6 g m^{-2}, to an area slightly larger than the actual plots. This number has been chosen to represent a potential future deposition rate that is 150% of the current annual dust deposition rate of 58 g m^{-2} in Utah [6]. We anticipate that 6-8 weekly dust applications will be the maximum needed to cause an early melt.

Survey forests (~75 forests, scattered across the Wasatch and Uinta ranges). These forests will be visited once each and minimally sampled. The forests are adjacent to active long-term USDA/NRCS SNOTEL and snow course sites (see letter of support from R. Julander). Forests will be photographed, and GPS coordinates, aspect, slope, and elevation recorded. A central forest location will be identified, and a 50 m x 3 m belt transect established running along the slope (up/down) if present or along the N-S axis. Tree species and DBH will be recorded for all trees at least 1.4 m tall along the belt transect. Wood cores of 5 trees each for the dominant species present will be collected with an increment borer, used to assess stand age, and archived. Multi-aged stands or those with considerable DBH variability will be cored more extensively. Soil pits will be excavated to 0.5 m depth (3 pits per forest) to collect soil and litter from the survey forests for analysis. On an intact pit wall, a 25 cm x 25 cm quadrat will be placed on the surface, and all litter (O-horizon) and top 10 cm of the mineral soil collected and saved.

List of attachments:

1. Locations of proposed sites
2. Instrumentation and activities at each forest
3. Letters of support

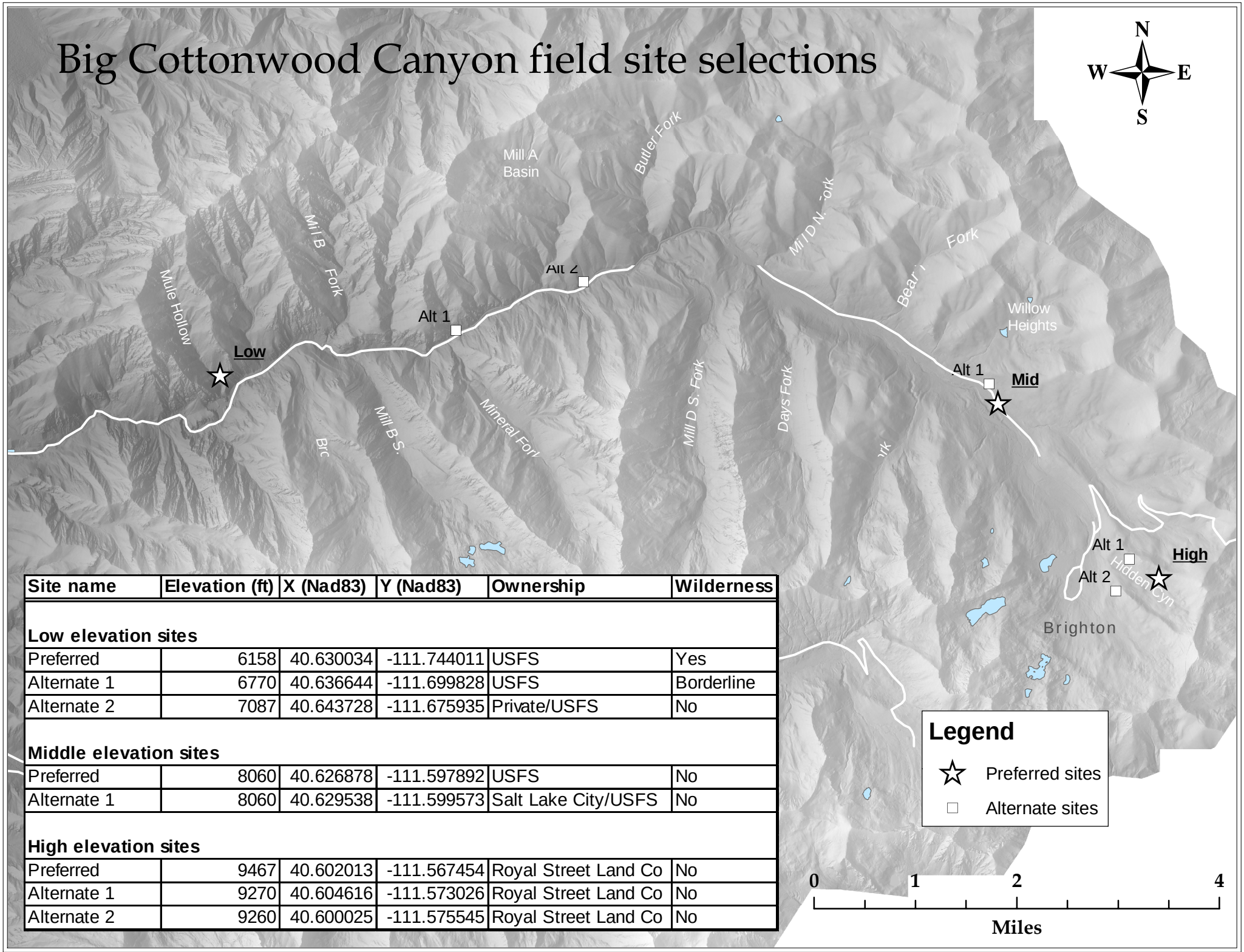
References:

1. Hamlet, A.F., et al., *Twentieth-century trends in runoff, evapotranspiration, and soil moisture in the western United States.* Journal of Climate, 2007. **20**(8): p. 1468-1486.
2. Barnett, T.P., et al., *Human-induced changes in the hydrology of the western United States.* Science, 2008. **319**(5866): p. 1080-1083.
3. Painter, T.H., et al., *Impact of disturbed desert soils on duration of mountain snow cover.* Geophysical Research Letters, 2007. **34**(12): p. doi:10.1029/2007GL030284, 2007.
4. Neff, J.C., et al., *Increasing eolian dust deposition in the western United States linked to human activity.* Nature Geoscience, 2008. **1**(3): p. 189-195.
5. Neff, J.C., et al., *Controls of bedrock geochemistry on soil and plant nutrients in southeastern Utah.* Ecosystems, 2006. **9**(6): p. 879-893.
6. Reheis, M.C., *Dust deposition in Nevada, California, and Utah, 1984-2002*. 2003, Open-file Report 03-138, U. S. Geological Survey.

Attachment 1

Locations of Proposed Sites

Big Cottonwood Canyon field site selections



Site name	Elevation (ft)	X (Nad83)	Y (Nad83)	Ownership	Wilderness
Low elevation sites					
Preferred	6158	40.630034	-111.744011	USFS	Yes
Alternate 1	6770	40.636644	-111.699828	USFS	Borderline
Alternate 2	7087	40.643728	-111.675935	Private/USFS	No
Middle elevation sites					
Preferred	8060	40.626878	-111.597892	USFS	No
Alternate 1	8060	40.629538	-111.599573	Salt Lake City/USFS	No
High elevation sites					
Preferred	9467	40.602013	-111.567454	Royal Street Land Co	No
Alternate 1	9270	40.604616	-111.573026	Royal Street Land Co	No
Alternate 2	9260	40.600025	-111.575545	Royal Street Land Co	No

Attachment 2
Instrumentation and Activities at Each Forest
(3 forest sites, one each at low, mid, and high elevation)

No. (per site)	Installed Equipment
1	Solar powered weather station (10 ft mast)
9	Soil moisture sensors (5, 20, 50 cm depths, installed in 3 replicate locations)
18	PVC soil collars – to measure soil respiration rate (on surface of soil, 4” dia. x 2” tall)
30	Sap flux sensors – to measure tree water use, at breast height in trunks
60	Mesh litter bags – to measure needle and root decomposition rate, 3”x3”, buried within a few cm of forest floor surface
18	Root ingrowth cores – to measure root growth, 2”diam x 4” deep
1	Small solar panels (20 W total power needed) and battery box
~	Associated dataloggers and wiring

Manual measurements and site visitation

Measurement	Season	Frequency
Soil respiration	Growing season	Biweekly
Under-snow respiration	Winter	Monthly, weekly during snowmelt
Snow water equivalent (SWE)	Winter	Monthly, weekly during snowmelt
Snow optical absorption	Winter	Monthly, weekly during snowmelt
Plant predawn water potential	Growing season	Biweekly
Shoot growth	Autumn	Once per year
Shoot needle area	Autumn	Once per year

Sample collection (at or adjacent to sites)

Sample collected	Season	Frequency
Branch samples (needles, shoot growth)	Late autumn	Once per year
Tree cores (growth increment)	Summer	Once, final year of experiment
Root biomass (ingrowth cores)	Autumn	Once per year
Litterbag collection	Spring, Autumn	Twice per year
Litterfall	Autumn	Once per year

Anticipated disturbances at the end of the study (likelyAutumn 2012)

This is an ecological field study designed to investigate natural forest processes, and our goal is to avoid disturbance entirely. Our sampling methods and chosen materials have been deliberately selected to minimize impact to the forest and the stream. No structures or concrete will be required, and the amount of visible equipment will be limited to the temporary weather station and soil surface collars. All visible equipment will be painted in forest colors where possible (the solar panel fronts are an exception).

All equipment will be removed at the end of the project. The small amount of sand we will use to accelerate snowmelt has trivial nutrient content. At the intended deposition rate (8 applications per year at $6g/m^2$) we will be applying only 27.6 kg of sand total over an area of 192 m^2 in each forest. The sand will be applied to upland slopes that are hundreds of yards distant from the streams of Big Cottonwood Canyon.

Attachment 3

Letters of Support

USDA United States Department of Agriculture | Forest Service | Uinta National Forest 88 West 100 North Provo, UT 84601 | Wasatch-Cache National Forest 125 South State Street Federal Building, Room 8236 Salt Lake City, Utah 84138

File Code: 1500
Date: June 30, 2008

Dave Bowling
University of Utah, Dept. of Biology
257 South 1400 East
Salt Lake City, UT 84105

Dear Professor Bowling,

My staff enjoyed meeting with you on 26 June 2008 regarding your proposed research. Our office is very interested in your project focused on climate change in the forests of our region. We have several GIS-based data sets for the Forest and surrounding area that may help you in site selection (although their spatial scope and temporal coverage are somewhat limited). These include fire history, timber harvest maps, and vegetation and soils maps. You are welcome to share these data at no charge by contacting our GIS manager, Teresa Rhoades, at 801-236-3444.

Based on our discussion, we generally see no problem in allowing your snowmelt timing manipulation studies at low, middle, and higher elevation sites on the Forest. Your research plan fits within the scope of allowable activities on the public lands we manage. Once you have preliminarily selected the sites, you need to contact the District Ranger and work with him to secure the necessary research permits and site surveys. The District Ranger for the Farmington Canyon and Cottonwood Canyon areas is Loren Kroenke. Loren can be reached by phone at (801) 733-2675, or at his office at 6944 South 3000 East, Salt Lake City, Utah 84121. Please feel free to contact Dave Myers, Deputy Forest Supervisor, or Reese Pope, Renewable Resources Staff Officer, at (801) 236-3400 if you have any further questions.

Sincerely,

Brian Ferebee

BRIAN FEREBEE
Forest Supervisor

cc: Loren M Kroenke, Dave Myers, Teresa Rhoades, Charlie Condrat

United States Department of Agriculture

NRCS
Natural Resources Conservation Service
245 N Jimmy Doolittle Rd
Salt Lake City, UT 84116
(801) 524-5213
FAX (801) 524-5564

To: Dr. David Bowling, University of Utah
From: Randall Julander
Date: July 7, 2008
Subject: Carbon Cycling Research

Dear Dave,

I'm glad to hear about your ideas to use the Utah snow survey data for ecological studies. My office will work with you to provide access to long-term datasets and meta-data for Utah snow course and snow survey SNOTEL sites to support your project. We have installed soil moisture sensors at all Utah sites over the last several years which should prove useful to your investigations of snowmelt timing and summer soil moisture. This is critical research that will assist in better understanding climate and carbon cycling in natural environments. I look forward to seeing the results.

Sincerely,

Randall P. Julander
Snow Survey Supervisor, NRCS, USDA.

The Natural Resources Conservation Service provides leadership in a partnership effort to help people conserve, maintain, and improve our natural resources and environment.

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