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Reynolds Creek Carbon Critical Zone Observatory

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Accomplishments

* What are the major goals of the project?

Priority 1: ***Landscape Soil Carbon Survey****: Create a landscape-distributed soil carbon and environmental dataset that can inform our understanding of the processes controlling soil carbon fate from the plot to the watershed scale.*

We will create a world-class landscape-scale soil carbon and environmental dataset that will provide a foundation for investigating intermediate scale processes that dictate soil carbon fate and elucidate the complex relationships between climate, landscape, and ecology. We will conduct a landscape soil carbon survey and produce an intermediate scale soil C map.

Priority 2: ***Environmental Monitoring Network****: Develop an integrated, watershed scale, instrumentation and monitoring network focused on soil carbon dynamics that is of value across hydrologic, ecologic, and geologic disciplines.*

We will develop an integrated, watershed scale, instrumentation and monitoring network focused on soil carbon dynamics but of value across the hydrologic, ecologic, and geologic disciplines. We will focus on intensive measurements of soil carbon and aboveground and belowground processes within the vicinity of the 5 eddy covariance towers (to be redeployed as part of this research, and referred to the CORE sites hereafter) as well as collection of limited groundwater and stream samples.

The process measurements at the CORE sites will include: a) eddy covariance upgrade and deployment to determine net ecosystem exchange (NEE), b) canopy transpiration and stand water use, c) aboveground biomass and limited aboveground net primary productivity (ANPP), d) Litter and soil organic carbon dynamics, e) manual soil CO_2 gas and soil respiration measurements, f) stream particulate organic carbon, dissolved organic carbon and inorganic carbon and groundwater.

Priority 3: ***Integrated Modeling Framework****: Develop an integrated modeling framework that can promote the evaluation of conceptual models of soil carbon behavior and associated interactions with climate, ecology, and landscape that can inform up-scaling mechanistic understanding to climate models.*

We will develop an integrated modeling framework that can promote the evaluation of conceptual models of soil carbon behavior and associated interactions with climate, ecology, and landscape to promote up-scaling of mechanistic understanding to climate models. The expected impact of modeling activities carried out by the RC CZO team is to develop and maintain an area of excellence in ecohydrology and biogeochemical modeling. We will achieve this impact both through modeling efforts by the RC CZO team, as well as by establishing collaborations and producing benchmark datasets that will be of broad interest to the Earth system modeling community. Throughout the cooperative agreement we will leverage these datasets to attract and develop a network of collaborators to expand support for complementary modeling activities in the RC CZO. Some of the complementary current projects where we will develop immediate collaborations include the NSF EPSCoR Track 2 Western Consortium for Watershed Analysis, Visualization, and Evaluation (WC-WAVE) award, Idaho's NSF EPSCoR Track 1 Managing Idaho's Landscapes for Ecosystems Services (MILES) agreement, a NSF CAREER grant to Co-PI Flores, and a NASA Terrestrial Ecology grant to Co-PIs Glenn and Flores.

* What was accomplished under these goals (you must provide information for at least one of the 4 categories below)?

Major Activities:

Priority 1: ***Landscape Soil Carbon Survey****: Create a landscape-distributed soil carbon and environmental dataset that can inform our understanding of the processes controlling soil carbon fate from the plot to the watershed scale.*

We continued to analyze soils across the entire watershed for soil inorganic and organic carbon and associated environmental properties to determine the ranges of values and the density of change in those values across the landscape. We identified indices of vegetation biomass/cover using remote sensed and LiDAR and hyperspectral data and examined vegetative controls on SOC distribution using the broad scale landscape soil C survey. We completed developing a soil carbon model for a subcatchment within Reynolds Creek to estimate the total soil carbon reservoir based on a linear-regression kriging approach with curvature as the main variable driving the distribution of soil C. This model was expanded to the entire watershed and is in development. Finally, we completed our initial study of controls and distribution of soil inorganic carbon across the watershed and quantified the carbonate rock coating contribution to total carbon storage.

We completed environmental characterization of elevation, aspect and vegetation controls on snow depth to understand the distribution of vegetation and likely soil carbon at Reynolds Creek. We completed analysis of a near surface geophysics study four seismic refraction profiles in Johnson Draw to investigate variations in deep weathering depth as a function of elevation and aspect and linkages to snow accumulation.

Priority 2: ***Environmental Monitoring Network****: Develop an integrated, watershed scale, instrumentation and monitoring network focused on soil carbon dynamics that is of value across hydrologic, ecologic, and geologic disciplines*
We continued to maintain and instrument the CORE sites as part of the environmental monitoring network and completed initial analyses of historic and new data sets. Specifically, we completed analysis of ten years of net ecosystem exchange data from two eddy covariance towers collected from the upper catchments. We reinstalled sap flux sensors at the three sagebrush CORE sites. We continued measurement of tree diameter increment

growth for NPP estimates using automated dendrometer bands and added additional manual bands and litterfall collectors. We completed analysis leaf- to ecosystem-level ecophysiological measurements to scale up plant level measurements. We maintained and recalibrated four forced diffusion (FD) chambers for collection of automated CO_2 flux at the CORE sites and one at Upper Sheep as well as maintained CO_2 and oxygen probes with soil depth at the three CORE sites over the growing season to quantify the spatial variability in these fluxes. We completed analysis of a near surface geophysics study using 3D time-lapse electrical resistivity arrays to evaluate three dimensional soil moisture variability at the CORE sites. We continued analysis of vegetation aboveground biomass and foliar tissue nitrogen with collection of LiDAR and hyperspectral data in the fall of 2014 (through collaborations with the NASA TE project), and coincident leaf and plot-level field data.

We completed a laboratory warming and wetting experiment to examine the processes controlling soil carbon storage where we incubated soils collected along a climate gradient at different temperatures and quantified the relative changes in soil organic carbon pool fractions. We completed a study examining rates of biological nitrogen (N) fixation associated with free-living biotic crust communities at the CORE sites to determine N inputs with elevation and possible nutrient constraints on plant productivity. Moreover, we examined the abundance and diversity of microbial community associated with these biotic crusts. We continued to analyses soil samples at 1, 2, 3 and 6-month post-burn intervals on different aspects in response to the Soda Fire. We continued monitoring wind erosion of materials in response to fire throughout the basin (Pierce NSF RAPID grant) and water erosion within a burned sub-watershed (Murphy Creek). We optimized our measurement of stream export of particulate and dissolved organic and inorganic carbon samples during the spring and summer of 2017 (scaled back on 2000 samples from 2016) to obtain event and high discharge-concentration data. We reinstalled 4 water chemistry sensors in the main stream and tributaries (Murphy (burned tributary), Tollgate (main stem), Outlet (main stem), Johnston (tributary) during the summer (when installation was safe). We repeated a stream water quality sampling in burned (Murphy) and unburned catchments to understand how stream chemistry and in-stream production changes temporally and spatially with stream drying. Finally, we continued a study examining groundwater contributions to stream runoff and carbon export in Reynolds Mountain East subwatershed and maintained three nested sets of Prenart tension lysimeters, temperature, moisture and matric potential probes within the catchment. Finally, Reynolds Creek CZO has been supporting the completion of analyses examining the long-term effects of experimental manipulations of precipitation and vegetation as well as soil thickness on soil carbon and nitrogen storage dynamics in a semi-arid ecosystem.

Priority 3: ***Integrated Modeling Framework****: Develop an integrated modeling framework that can promote the evaluation of conceptual models of soil carbon behavior and associated* *interactions with climate, ecology, and landscape that can inform up-scaling mechanistic understanding to climate models*

We completed production of model forcing data set for Reynolds Creek to include incoming solar radiation and preliminary run of BIOME BGC, a process based model used to estimate fluxes and storage of energy, water, carbon, and nitrogen for the vegetation and soil components of terrestrial ecosystems, with forcing data set. Specifically, we are using Biome-BGC model to simulate the distribution of SOC at spatial resolutions coincident with the fine-resolution forcing data. We expect that the derived spatial distribution of SOC will perform poorly in areas of Reynolds Creek CZO where there is a reason to suspect that: (1) topographic redistribution of moisture results in either a depletion or supplement of soil water relative to the difference between atmospheric demand and precipitation, and (2) disturbance and/or vegetation succession has significantly changed in such a way that is not reflected in the current observed distribution of plant functional types used to constrain litter inputs in Biome-BGC. These activities were initiated in Yr 4 and will be completed in Yr 5. In parallel, we initiated in Yr 4 an instance of an advanced ecohydrologic model, ParFlow, which can resolve hillslope-scale redistribution of moisture, as well as surface water-groundwater interactions and, potentially, the influence of deeper-CZ structure on land-atmosphere exchange.

Year 4 demonstrated the emergence of Reynolds Creek CZO as a testbed for the modeling community. Reynolds Creek CZO has served as a platform for a number of modeling studies, including: (1) a partnership with terrestrial ecosystem modelers at the University of Montana described in more detail below, (2) activities conducted in support of an NSF INSPIRE grant to improve representation of hydrologic processes in the global land model CLM (Ying Reinfelder, Rutgers University, PI), (3) application of the reactive transport version of the Pennsylvania Integrated Hydrologic Model (RT-PIHM) for cross-site experiments being led by Li Li (Penn State University), and 4) IML CZO activities modeling using EC tower data from RC CZO. We also engaged with colleagues in the CZO, LTER, NEON, and CSDMS communities to build a community of practice organized around modeling. Two cross CZO modeling workshops have been organized for year 5.

Specific Objectives:

Priority 1: *Landscape Soil Carbon Survey: Creation of a landscape-distributed soil carbon and environmental dataset that can inform our understanding of the processes controlling soil carbon fate from the plot to the watershed scale.*

1.1 Soil organic matter-vegetation associations

Complete analysis of soil bulk density relationships for felsic and mafic materials to estimate bulk density from SOC and SOM where bulk density measurements are not available. Develop a correction term using coarse fraction materials from bulk sample to estimate fine fraction bulk density from field bulk density. Complete analysis of soil organic carbon-vegetation associations using vegetation indices from remotely sensed as well as airborne LiDAR and hyperspectral data. Map distribution of soil organic carbon based on these relationships.

1.2 Mobile Regolith and Bedrock Mapping

Quantify the relationships between total mobile regolith depths and different topographic variables in a granitic watershed and map soil depth. Evaluate generality of relationships between soil depth and curvatures across sites available from global dataset (including JRB and BC CZOs). Acquire and process seismic refraction dataset in Johnson Draw to investigate variations in deep weathering depth as a function of elevation and aspect.

1.3 Topographic controls on carbon storage

Complete quantifying the relationship between measurable local topographic features and soil depth to improve estimation of deep soil carbon across complex terrain. Develop map for entire watershed based on regression kriging using curvature as a covariate.

1.4 Climate and Geologic Controls on soil inorganic carbon (SIC)

Complete analysis of quantifying role of carbonate coating of rocks in storing deep inorganic carbon. Complete analysis and maps of soil inorganic carbon at pedon scale across the watershed to determine the importance and role of different state factors in controlling soil inorganic carbon presence and amount.

1.5 Snow Mapping

Complete re-analysis of snow-elevation distribution from RCEW using LiDAR and association with vegetation and aspect to revise manuscript for publication

Priority 2: Environmental Monitoring Network: *Develop an integrated, watershed scale, instrumentation and monitoring network focused on soil carbon dynamics that is of value across hydrologic, ecologic, and geologic disciplines*

2.1 Net Ecosystem Exchange (Eddy Covariance Towers)

Maintain eddy covariance and heat flux sensors at 4 CORE sites and establish presence on Ameriflux Network. Complete analysis of subset of 2002-2010 net ecosystem exchange (carbon flux) data associated with 4-5 eddy covariance towers in upper portion of catchment.

2.2 Transpiration (Sap Flux Sensors)

Maintain, replace, and download aspen and conifer tree CORE sites sap flux sensors. Maintain tissue-heat-balance sap flux sensors (5-6 per site) at three sagebrush CORE sites.

2.3. Plant ecophysiology

Conduct leaf- to ecosystem-level physiological measurements of carbon and water fluxes to scale plant level water measurements to ecosystem scale

2.4 Soil Respiration

Maintain eight Vaisala CO_2 sensors along with soil temperature and moisture sensors (Hydra Probe) at the Low Sage, Big Mountain Sage, and Wyoming Big sagebrush sites. Estimate net CO_2 flux from the soil based on measured gas concentration gradients and porosity and to determine depths of CO_2production in the soil. Maintain automated Forced Diffusion (FD) chambers at CORE sites to measure soil CO_2 effluxes. Continue manual measurements of soil CO_2 effluxes at CORE sites to capture spatial heterogeneity of soil respiration.

2.5 Aboveground Biomass and Net Primary Productivity

Expand long-term vegetation monitoring from 3 sites to 5 sites per vegetation type. Assess drone technology to quantify cover and greenness. Continue diameter increment growth measurements with Treehugger automated dendrometers and install manual dendrometer bands at tree sites. Measure litterfall production at tree sites and sagebrush steppe CORE and satellite sites.

2.6 Soil Carbon Dynamics and Microbial Profiling

Complete an incubation study of soils collected along the watershed elevation gradient to understand the controls on sensitivity of different elevations and SOC pools to decomposition in response to temperature changes

2.7 Nitrogen Fixation, Dynamics and Biological Crust Bacterial Abundance and Diversity

Complete analysis of biological crust sampling focused on quantifying biological N fixation rates and nutrient dynamics and complete characterization of associated microbial communities (using 16-S RNA analysis) across the watershed elevation gradient.

2.8 Near surface soil moisture and critical zone structure using geophysics

Complete collection of 3D electrical resistivity tomography (ERT) data at the Nancy Gulch, Lower Sheep, and Reynolds Mountain East Core Sites to understanding spatial variability in near surface soil moisture.

2.9 Wildfire Responses

Continue to collect dust, erosion, and water samples within burned catchment (Murphy Creek). Analyze soils collected 1,2, 3, 6 month following fire to evaluate losses and changes in soil properties. Complete analyses of productivity and respiration responses of montane sagebrush ecosystem to prescribed fire.

2.10 Stream Export

Analyze particulate and nutrient data associated with 2015 and 2016 collection. Analyze first year of data collected on fine-resolution spatial and temporal variability in stream chemistry and collect second year of data in drying intermittent streams. Initiate study on study of water sources to streams in headwater catchments including installing lysimeters and collecting groundwater samples.

2.11 Long-term experimental manipulations of precipitation, vegetation, and soil thickness

Complete analyses of evaluating the role of soil depth in controlling storage of water, carbon and nitrogen in sagebrush steppe ecosystem receiving experimentally augmented precipitation.

Priority 3*: Integrated Modeling Framework:* *Develop an integrated modeling framework that can promote the evaluation of conceptual models of soil carbon behavior and associated interactions with climate, ecology, and landscape that can inform up-scaling mechanistic understanding to climate models*

3.1 Fine-Resolution Forcing Data

Complete analysis of 31-year record for relative humidity, air temperature, dew point, precipitation amount, and the precipitation phase and publish data paper. Complete analysis of incoming solar radiation to complete dataset for ecosystem modeling.

3.2 Modeling the Spatial Distribution of Soil Organic Carbon

Complete BIOME BGC runs using 31 yr forcing data set and compare predicted against observed soil carbon distribution. Write manuscript on results.

3.3 Integrated Hydrologic Modeling in Reynolds Creek

Design and initiate implementation of a suite of numerical experiments that examine the role of the deeper CZ in supporting terrestrial vegetation during periods of extended drought using ParFlow.

3.4. The Reynolds Creek CZO as a Community CZ Modeling Platform and

Establish Reynolds Creek as a community CZ modeling platform.

3.5 Engaging with the Broader Integrated Modeling Community

Engage with colleagues in the CZO, LTER, NEON, and CSDMS communities to build a community of practice organized around modeling.

Significant Results:

Priority 1: *Landscape Soil Carbon Survey*

1.1 Soil organic matter-vegetation associations

Vegetation indices calculated from spectral data are the best predictors of SOC storage (Figure 1.1a) (Will, 2017, Will *et al.*, 2017). Strong relationships between field bulk density and % soil organic matter (SOM) as well as soil organic carbon (SOC) were derived for felsic (granite, rhyolite) and mafic (volcanic, basalt) parent materials (Figure 1.1b) and validated (Figure 1.1c) (Patton *et al.*, *in review*).

1.2 Mobile Regolith and Bedrock Mapping

A strong inverse linear relationship was observed between mobile regolith thickness (TMR) and curvature (r^2=0.89) and a predictive map of TMR in Johnston Draw was produced (Figure 1.2a) (Patton *et al.*, *in review*) and a simple model developed to predict soil thickness at any location within a catchment with fine resolution data and a few soil measurements (see Key Outcomes).

Geophysical measurements showed that average depth to the top of unweathered bedrock and the depth to the top of fractured bedrock increased with decreasing elevations (Figure 1.2c). The largest difference in weathering depth between the two aspects occurred where the difference in snow accumulation (Nielsen *et al.*, *in preparation*) (see Key Outcomes).

1.3 Topographic controls on carbon storage

Accurate models for the spatial distribution of SOC from the soil surface to saprolite that incorporates local controls of aspect and topography were completed (Patton *et al.*, *in review*, Figure 1.3a) (See Key Outcomes). North-facing aspects had 3.0 times more total SOC per area than the south-facing aspects, and convergent areas had 6.4 times more total SOC per area compared to divergent areas. Soil organic carbon below 0.3 and 1 m depth was > 80 and 30 % of the total catchment SOC indicating substantial underestimation of SOC stocks if sampled at shallower specified depths (Figure 1.3b, Patton *et al.*, *in review*). Regression kriging modeling techniques using curvature as a covariate emerges as the best model for predicting soil carbon (r^2=0.82) (Figure 1.3c) and hold promise to estimate soil carbon across entire watershed (r^2=0.75, 75 pits, 20 test, 50 build) (Figure 1.3d)

1.4 Climate and Geologic Controls on Soil inorganic carbon (SIC)

Rock carbonate coating were quantified for the first time and can represent as much as 43% of total IC (mean 13%) stored in the gravel fraction (Figure 1.4a) (Stanbery *et al.*, 2017). Precipitation was a primary control on SIC accumulation, with the mean annual precipitation of 500 mm as the threshold for SIC accumulation (Figure 1.4b) (Stanbery *et al., in review*).

1.1 Snow Mapping

Smaller distances between freezing levels and elevations of significant storage indicate greater sensitivity at RC CZO to changes from snow to rain (Tennant *et al.* 2017) (see Key Outcomes).

Priority 2: Environmental Monitoring Network

2.1 Net Ecosystem Exchange (EC Towers)

Sagebrush steppe ecosystems are carbon sinks for carbon in wetter years (WY 2016) compared to drier years where sites switch from slight sources to carbon sinks at higher elevation (WY2015) (Flerchinger *et al.*, *in review) (Figure 2.1a)*. Annual precipitation did not explain cumulative growing season GEE. Rather, sagebrush Gross ecosystem exchange (GEE) varied with spring and summer rain and aspen GEE responded to spring snowpack conditions (Fellows *et al., in review*) (Figure 2.1b).

2.2 Transpiration (Sap Flux Sensors)

Sap flux measurements show that aspen fluxes are greater than mixed conifer fluxes (Figure 2.2).

2.3. Plant ecophysiological ecology

Growing season leaf to ecosystem level measurements at the sagebrush CORE sites showed different environmental water and carbon flux across sites (Figure 2.3) (Sharma *et al., in review*)

2.4 Soil Respiration

Growing season CO_2 fluxes in 2015 ranged from 36-104 g CO_2-C/m^2 and were 1.5-3x higher at Upper Sheep (USC) than other sites (Figure 2.4) (Lohse et al. in progress).

2.5 Aboveground Biomass (AGB) and Net Primary Productivity (NPP)

Rotor-wing UAV replaced camera-pole technology for acquiring very-high resolution NDV-IR imagery used for assessing species cover within plant diversity plots and bare ground and plant canopy patch size and continuity within site macro-plots (Figure 2.5).

2.6. Soil Carbon Dynamics and Microbial Profiling

Absolute cumulative C respiration and average observed temperature sensitivity (Q_{10}) was highest at the highest elevation but a greater temperature response per unit C was observed at the lowest elevation (Figure 2.6) (Delvinne et al. in review). Sand was the best predictor of sensitivity to carbon loss suggesting accessibility to carbon rather than recalcitrance determines sensitivity to carbon loss.

2.7. Nitrogen Fixation, Dynamics and Biological Crust Bacterial Abundance and Diversity

Warmer, drier climates at lower elevations hosted greater biocrust cover and higher nitrogenase activity compared with colder, wetter climates at higher elevations (Figure 2.7a, Schwabedissen *et al.,* 2017). We detected dramatic shifts in the abundance of individual N_2-fixing groups (i.e., cyanobacteria, symbiotic, other) as elevation increased (Schwabedissen *et al., in review*) (Figure 2.7b) The phylum Actinobacteria represented the majority of the bacterial community (36-51%)(Blay *et al.,* 2017) (Figure 2.7c).

2.8 Near surface soil moisture and critical zone structure using geophysics

Analyses indicate high spatial heterogeneity in water flow and distribution over the 7x8 m plot scale. However, distribution over time appears relatively stable (Nielsen 2017) (Figure 2.8)

2.9. Wildfire Responses

Sediment delivery was mainly by wind in first few months post-fire and from runoff during low intensity rainfall and snowmelt events the first autumn and winter seasons after the fire (Figure 2.9a, Vega et al., in progress). We note that particulate organic carbon from the burned watershed (Murphy) are 5-20 times higher than background concentrations (Figure 2.10b). Significant temporal patterns were observed in coarse fraction and texture following fire (n=64) (Figure 2.9b, Patton et al. in progress). Gross ecosystem productivity recovers rapidly following prescribed fires in montane sagebrush ecosystems (Figure 2.9c).

2.10. Stream Export

Particulate organic matter and suspended sediment in streams are highly correlated (r^2> 0.95) (Figure 2.10a). Concentrations of DOC and DIC increased over the course of stream drying from April to June and show distinct spatial and longitudinal patterns (Figure 2.10b) (Macneille et al., in progress).

2.11. **Long-term experimental manipulations of precipitation, vegetation, and soil thickness**

Results show that experimentally manipulation of soil depth can strongly modulate soil water, carbon and nitrogen storage in response to long-term altered precipitation (Figure 11) (Huber et al., in preparation).

Priority 3*:* Integrated Modeling Framework*:*

3.1 Fine-Resolution Forcing Data

A data paper on the fine-resolution, spatially explicit, forcing model input data from historic climate datasets for 239 km^2 of RCEW is in review (Kormos *et al.,* in review) (Figure 3.1) and datasets and Digital object identifier (DOI) datasets are available at BSU Scholar Works (Kormos *et al.,* 2016).

3.2 Modeling the Spatial Distribution of Soil Organic Carbon

We completed BIOME-BGC runs and are commencing to analyze results.

3.3 Integrated Hydrologic Modeling in Reynolds Creek

We initiated design and implementation of ParFlow. We expect results from these experiments to evaluate observed hydrologic dynamics in the watershed and to be submitted as manuscripts.

3.4. The Reynolds Creek CZO as a Community CZ Modeling Platform

Reynolds Creek CZO served as a platform for at least 4 externally engaged modeling activities

3.5 Engaging with the Broader Integrated Modeling Community

Two cross CZO modeling workshops have been organized in yr 5 to build a community of practice organized around modeling.

Key outcomes or Other achievements:

The Reynolds Creek CZO seeks to understand the role of soil environmental variables that vary across complex terrain in governing soil carbon storage and turnover in a semi-arid environment. Our overarching hypothesis is that *soil environmental variables (e.g. soil water content, soil temperature, soil depth, and net water flux) measured and modeled at the pedon and watershed scale will improve our understanding and prediction of SC storage, flux, and processes.*

Environmental forcing data Unique benchmark datasets document temperature increases and shifts in the snow to rain transition with elevation at Reynolds Creek CZO over the past 30 years and a dataset in Johnston Draw, a subwatershed in Reynolds Creek, documents this in finer detail. These are available to the broader modeling community through data publications and DOIs (Kormos *et al.,* 2016, Kormos *et al.,* in review, Kormos et al. 2017, Godsey et al. in review, Enslin et al. 2016). Tennant et al. (2017) also document trends in snow-elevation storage using LiDAR and shows that there is a relatively short distance in elevation between freezing levels and elevations of significant storage indicating greater sensitivity at RC CZO to changes from snow to rain (Key Outcomes Figure 1, Tennant *et al.,* 2017). The importance of vegetation in RC CZO to snow storage is also documented and indicates that changes in vegetation cover, because of drought or wildfire, could drive changes in the spatial distribution of snow storage. Eddy covariance data from three CORE sites is available on Ameriflux and facilitating making RC CZO a community CZ and ecological modeling platform (108 downloads total to date).

Mobile Regolith and Bedrock Mapping Soil depth is a fundamental variable in earth system sciences, yet soil depth remains difficult to predict across complex terrain. We have discovered a simple empirical model to predict soil thickness at *any* location within a catchment using high-resolution digital elevation models and a limited number of soil thickness measurements (Patton *et al., in review*). Indeed, we show that there is a general inverse relationship between hillslope curvature and TMR across a diverse dataset (Key Outcomes Figure 2), although the slopes and intercepts vary. We find that the slopes of these functions vary with the spread in the catchment curvature distributions as measured by the standard deviation and that the curvature distributions all center on planar surfaces (0 m^{-1}). The significance of the curvature distributions being normally distributed and centered on 0 m^{-1} is that the intercept of the curvature-TMR function represents the most frequent thickness of mobile regolith within each catchment. We conduct independent tests of this model using data from three catchments with varying catchment curvature distributions and lithologies. Consistent with our expectations, we show that the observed TMR values agree well with predicted values in two catchments with narrow catchment curvature distributions regardless of lithology (N=6-8, r^2=0.72-0.79, RMSE=0.14-0.3 m, $p<0.02$), whereas performance is lower in a catchment with a broad curvature distribution (N=163, slope=0.53, r^2=0.21, RMSE=0.20 m, $p<0.0001$) (Key Outcomes Figure 3). Despite lower relative performance in catchments with broader catchment curvature distributions, the utility of the TMR-curvature model is that it can be used to improve site selection and reduce physical and monetary costs of interpolated TMR estimates (based on the curvature distributions). Perhaps more importantly, the TMR-curvature model outperforms kriging-based interpolations of soil thickness in these areas suggesting that it can produce more reliable results with significantly less labor and cost. *Deep couplings of critical zone* Geophysical measurements showed that average depth to the top of unweathered bedrock and the depth to the top of fractured bedrock increased with decreasing elevations. The largest difference in weathering depth between the two aspects occurred where the difference in snow accumulation (Key Outcome Figure 4, Nielsen *et al.*, in prep). This increase in weathering extent at lower elevations is similar to what was observed in soil weathering along elevation gradients above the rain-snow transition by *Riebe et al.* (2004a), *Dahlgren et al.* (1997), and *Rasmussen et al.* (2010). These findings suggests that elevation and dominant precipitation are a control on the depth to unweathered bedrock within Johnston Draw and likely throughout Reynolds Creek. Given that we have been documenting changes in the rain to snow transition over the past 30 years, these findings point to deep coupling between climate and weathering extent and likely changes in weathering that will come in the future as the Reynolds Creek critical zone transitions to a snow free zone.

Landscape carbon survey Much uncertainty in soil carbon budgets stems from distributing soil carbon across complex terrain where soil depth is largely unknown. To date, soil carbon models in complex terrain have used local controls such as vegetation cover, slope, elevation, hillslope position and soil properties to distribute soil carbon. For the first time, we can accurately predict soil carbon to saprolite (r^2=0.75), and we can quantity the entire watershed carbon stores. We show that regression kriging using curvature as a covariate improves this prediction of soil carbon (r^2=0.82). Our findings indicate that a significant amount of carbon is stored deep in critical zone and that some agency and large-scale research efforts that sample between 30 and 100 cm depth vastly underestimate total soil carbon stores on complex terrain (Patton *et al.,* in review). Results from this study also indicate that the processes responsible for carbon sequestration in soils vary spatially at relatively small scales and that they can be described in a deterministic fashion given adequate elevation data.

Understanding processes controlling carbon storage We document that montane sagebrush ecosystems are large carbon sinks (150 g/m^2) and lower elevation carbon uptake determined by annual water storage (Flerchinger *et al.*, in review). Temperature sensitivity of SOC decomposition strongly differs across the landscape in semi-arid ecosystems. Increased temperature will lead to a greater quantity of CO_2 release at higher elevations owing to a greater soil C concentration, but the sensitivity of soil C decomposition to increasing temperatures appears to be greater at lower elevations. Differences in temperature sensitivity (i.e. temperature response of decomposition for 5°C and 15°C temperature increments, Q10) was explained by percent sand. The greater sensitivity at lower elevations was governed largely by availability, rather than quality of SOC (Delvinne *et al.,* in review).

Controls on carbon uptake and responses to fire Most studies are conducted at the plot scale, but processes that operate at larger spatial and temporal scales such as fire and vegetation change may ultimately determine the impact of soil on the global budget (Westerling *et al.*, 2006; Trumbore and Czimczik, 2008). We show significant amounts of sediment and organic matter that are being wind transported to leeward hollows and swales creating drifts following the Soda Fire. Sediment delivery is mainly by wind in first few months post-fire, primarily from north aspect swales, and then from runoff during low intensity rainfall and snowmelt events the first autumn and winter seasons after the fire (Vega *et al.*, in progress). Finally, we document rapid recovery of carbon uptake as measured by NEE (within a year following a prescribedfire) in a montane sagebrush steppe ecosystem suggesting the prescribed fire in montane sagebrush system may be an effective management tool (Fellows *et al.*, in review).

* What opportunities for training and professional development has the project provided?

With a reduced budget for year 4, we were able to support research and/or salary (partial, summer, and/or full) for 10 graduates students (50% women), 2 postdoctoral associates, 5 undergraduates, and X high school students, through a combination of diversified funding sources (ISU and BSU teaching assistantships, collaborations, grant funding). Another set of graduate students (3 at BSU) and postdocs (2 at BSU) are aligned with the Reynolds Creek CZO (salary not funded by CZO but enabled by investments in CZO). Most post-docs, graduate students and undergraduates work with several of the Reynolds Creek CZO PIs whose expertise range across geoscience, soil science, plant sciences, microbiology, hydrology, plant physiological ecology, stream ecology and geomorphology. Students freely interact across departments and universities and agencies (Idaho State University, Boise State University, and USDA ARS), and this training promotes the development of a critical mass of critical zone scientists.

Meetings: We have weekly meetings via video conferencing with all RC CZO participants to discuss research issues and future activities and have graduate students and postdoctoral students present their research and debate findings. Weekly meeting are important to ensure interactions among the students and PIs across institutions. Presentations provide an opportunity to hone their speaking skills and sharpen their research efforts and also identify synergies/collaborations with the other students. We discuss research findings, future plans and ways to connect our research elements in the critical zone. We support graduate students to attend regional and national meetings and work closely with them to prepare them for presentations and to advise them on manuscript preparation (See Products). Some of PIs (Lohse, Seyfried, Glenn) spend considerable time in the field with graduate students, training them in field methods and developing measurement procedures, and then others in the lab to teach analytical and modeling methods (Flores, Benner, Lohse). In April 2017, Lohse organized a planning meeting to discuss key findings and future planning for the Reynolds Creek CZO II or other funding prospects. In October 2017, Reynolds Creek had its annual meeting at ISU to report key findings from year 4 and plan for year 5.
Coursework: We have also continued to integrate critical zone science into our courses and developed new ones. In Fall 2017, Lohse is leading an *Advanced Topics in Biogeochemistry*seminar and having students lead a review of key findings from the CZO and organizing the review around critical zone services. In the spring, Lohse continue to integrate research data into her Ecosystem course and will develop a set of labs for general ecology examining the mechanisms of juniper encroachment. In 2015 at Idaho State University, we developed curriculum for an environmental methods course (2 week, intensive summer field (4 credits) focusing on water and carbon in the critical zone in the spring and implemented it for the first time from May 18-May 30, 2015 with the participation and expertise of 4 CZO investigators, Lohse (soil scientist), Crosby (geomorphology, lead on course), Godsey (hydrologist), and Reinhardt (plant physiological ecologist). This course is being revamped for Summer 2017 and being incorporated into Godsey's CAREER proposal.
Mentoring: RC CZO disseminated guidelines for mentoring postdoctoral and graduate students. Senior participants use these guidelines in concert with their experience to mentor junior participants: faculty mentor postdocs, graduate students, and undergraduate students; postdocs mentor graduate and undergraduate students; graduate students mentor undergraduate students.

* How have the results been disseminated to communities of interest?

Stakeholder engagement: USDA ARS has continued to organize semi- to annual meetings with the stakeholders (ranchers and private landowners (20+), Bureau of Land Management) to communicate and discuss activities and identify new areas of research activities that might affect different stakeholders. In particular, meetings and discussions were extensive to evaluate post-

wildlife responses. RC CZO has continued to use the ARS as the “gatekeeper” to coordinate and communicate with private landowners and BLM including obtaining permissions and schedule sampling/flights and other activities on different sites across the RCEW.
RC CZO as growing magnet for an interdisciplinary scientific community: RCEW continues to be a focus of hydrologic field research, instrument development and process-oriented modeling averaging use of 100 visitor nights/year. RC CZO has increased levels of activity from the ecology and biogeochemistry communities, resulting in exciting “cross-fertilization” that results in productive science. Visitors/year has increased from an average of 100/yr to 250 in 2015, 423 visitors in 2016, to 232 in 2017 (as of September 2017 with 100+ projected). To broaden participation of external researchers, Lohse and team submitted a NSF FSML proposal in Dec 2016 to build a Living and Educational Facility (LEF). Senior personnel (Lohse, Seyfried, Pierson, Flores) plan to re-submit this proposal to augment the facility and equipment at the Reynolds Creek field station to enhance engagement and research of a broader community and outreach facilities.
Engage broader scientific community: We continue to engage different networks in the RC CZO and CZO network science. We continue to engage Idaho NSF EPSCoR (quarterly newsletter serves over 500 scientists and educators within and outside Idaho) and the NSF EPSCoR Western Tri-State Consortium (ID, NV, NM) and capitalize on products (e.g. downscaled climate scenarios, modeling, visualization) that can be applied to the RC CZO. We have also engaged other National networks through senior personnel involvement, including UCAR, NEON, OpenTopography, LTERs, EarthCube, LTAR, and CUASHI. In yr 4, we engaged with the Long-term Agricultural Research (LTAR) Network with the advent of Reynolds Creek Experimental Watershed also being selected as an official LTAR site. This selection along with CZO has resulted in major infrastructure investments in refurbishment of 5 eddy covariance instruments and new investments in soil carbon dioxide probes, invited talks at LTAR sessions, cross fertilization with other LTAR sites, particularly the SWRC in Tucson. Indeed, with the Soda Fire that burned over 1100 km^2, and 68 km^2 of Reynolds Creek during the week of Aug 10, 2015 resulted in a mobilization of ARS scientists (remote sensing and interest in post-burn instrumentation). Reynolds Creek is providing the ARS with critical data to parameterize BAER modeling efforts.

In year 4, we engaged with landscape ecology modelers from University of Montana, now NASA, to examine the role of phenology in driving patterns of productivity in sagebrush steppe ecosystems using the eddy covariance data and other supporting data. Externally engaged modelers at University of Montana (Drs. Renwick and Poulter) using CORE site data found that the existing phenology types defined in the LPJ-GUESS DGVM could not adequately capture the seasonal patterns of gross primary productivity (GPP) observed at the four study sites. The model was improved substantially by a) developing a new “semi-deciduous” phenology type to represent sagebrush, and b) optimizing model parameters using site-level GPP data coupled with remotely-sensed LAI data (Renwick et al. in preparation). Lohse also engaged with outside collaborators at Stanford, Robert Jackson and his graduate student, to examine the role of soil thickness on root distributions. They toured RC CZO in October 2017 and received archived roots for analysis. Finally, RC CZO engaged with College of Western Idaho, a community college in Nampa, and Dr. Melissa Schlegel who teaches there to explore possible synergies with the college and engaging her in research given her expertise in groundwater isotope geochemistry.

Data availability and management: We have published multiple categories of historical datasets to present data (2016) from Reynolds Creek Experimental Watershed on the criticalzone.org website. These datasets encompass baseline monitoring data sets including precipitation data from 24 rain gages from 1962-2016, soil moisture and evapotranspiration for multiple stations from 1977-2016, soil temperature from multiple stations from 1971-2016, stream flow from 10 weirs from 1963-2016. We strive to make our data rapidly available to the general public and cross CZOs to increase participation ad discoverability. In Year 4, we submitted a data paper based on our 31 years of hourly, 10 m raster model outputs for many of these forcing data and others with DOI (24TB) (Kormos et al, 2016, Kormos et al., *2017*). Moreover, we published a unique 10-year data set and data paper associated with the rain to snow transition and micrometeorology associated with this subcatchment (Enslin et al. 2016; Godsey et al. in review). Aboveground biomass and cover derived from LiDAR data has also be published for the entire Reynolds Creek CZO. We have also published our soil carbon (Will et al. 2017; Patton et al; 2017) and soil mobile regolith thickness and property estimates (Patton et al., 2017). Finally, we have also posted our eddy covariance tower data to Ameriflux and to date have had 36 data downloads.

Public Outreach We have worked to continue to engage the public in Critical Zone science and importance of soils as the foundation of terrestrial biomes and in providing many ecosystems and critical zone services (See Impacts on society). We participated in the Idaho State University STEM data outreach event (100+ students engaged directly), and the Pocatello Environmental Fair (100+ members of the public directly engaged). At RCEW, we implemented Owyhee Hydrology Camp in which 5 local high school students plus 2 chaperones came out to Reynolds for two days to learn about soils and hydrology and the science conducted at Reynolds Creek. We also repeated our an 8th grade adventure learning expedition (4rd in row) at Reynolds Creek in which the McCall Outdoor Science School (MOSS) lead adventure learning in the RCEW for 23 students and 2 chaperones for 2 overnights at Reynolds Creek. Finally, Dr. Sarah Godsey and Ruth MacNeille initiated an informal educational program to broaden participation in STEM and spent an afternoon with ~20 Shoshone-Bannock tribal youth and advisors in the field integrating art, native stories about flooding, and hands-on critical zone science.

In year 4, we also focused attention on engaging the public through informal education such as documentaries and a virtual watershed tour. *Voices of Fire is* a documentary that presents the different perspectives of the Soda Fire, a 200,000-acre fire that swept through the RC CZO, and presents different perspectives of management of the Reynolds Creek Watershed prior to and after the burn. On August 10 and 30th 2017, *Voices of Fire*, premiered on Montana Public Television and then Idaho Public Television. We have also embedded this film into the criticalzone.org site (http://criticalzone.org/reynolds/education-outreach/) to make it publically available. As another element of our public outreach, we completed Reynolds Creek Virtual Watershed Tour (http://reynoldscreekczo.org/wordpress/). Videos were collected and interviews conducted during the summer of 2016 at RC CZO and resulted in the production of 14, 2-4 minute videos as part of a Virtual Watershed Tour on subwatershed research topics. Sindelar will incorporate animations to explain concepts discussed in the videos as part of year 5.

* What do you plan to do during the next reporting period to accomplish the goals?

Major Priority Area	**Activity**	**Milestones**											
		Year 5	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Strategic Priority 1: ***Landscape Soil Carbon Survey***	**Survey**	Year 5 revised soil carbon map finalized and published												
	Characterization	Complete Year 3-5 soil analysis												
		Complete publications of data DOIs for soils	X	X	X	X	X	X	X	X	X	X	X	X
Strategic Priority 2: ***Environmental Monitoring Network***	**Core Site Creation**	Complete installation and monitoring at 5 of 5 sites.						X	X	X	X			
	Net Ecosystem Exchange	Maintain sites and monitoring continued Analyses continued on historic data	X	X	X	X	X	X	X	X	X	X	X	X
	Transpiration	All sap flux sites maintained,	X	X	X	X	X	X	X	X	X	X	X	X

Major Priority Area	Activity	Milestones											
		Year 5	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
		monitored												
	Soil Respiration	Continue automated and manual soil flux measurements	X	X	X	X	X	X	X	X	X	X	X	X
	Stream and Groundwater Carbon Export	Complete stream, soil-water, groundwater study and publish datasets DOIs	X	X	X	X	X	X	X	X	X	X	X	X
Strategic Priority 3: ***Integrated Modeling Framework***	**Integrated Terrestrial Biosphere Modeling**	Complete integration of fine-resolution climate data with soil carbon and other environmental variables Complete BIOME BGC simulations	X	X	X	X	X	X	X	X	X	X	X	X
	Integrated Terrestrial Biosphere Modeling	Complete initial simulations using ParFlow model (leveraged from other	X	X	X	X	X	X	X	X	X	X		

Major Priority Area	Activity	Milestones											
		Year 5	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
		projects)												
	RC CZO as community modeling platform	Continue to make data accessible via DOIs	X	X	X	X	X	X	X	X	X	X	X	X
	Cross CZO modeling	Organize and hold a Cross-CZO modeling workshop in Spring 2018	X	X	X	X	X							

Supporting Files

	Filename	Description
(Download)	Figures Priority 1 2017 low res.pdf	Figures for Results for Priority 1
(Download)	Figures Priority 2 2017 low res.pdf	Figures for Result for Priority 2
(Download)	Key Outcomes 2017 low res.pdf	Key Outcomes
(Download)	Special Reporting RequirementsFINAL.pdf	Special reporting requirements s

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Products

Books

Book Chapters

Inventions

Journals or Juried Conference Papers

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- Sharma, H., Reinhardt, K., Lohse, A., and K. Aho (2017). Variation in carbon and water fluxes in sagebrush steppe communities along an elevation gradient spanning rain- to snow- dominated precipitation regimes. *Agricultural and Forest Meteorology*. . Status = UNDER_REVIEW; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes
- Stanbery, C., Pierce, J.L., Benner, S.G., and K. Lohse (2017). On the rocks: quantifying storage of inorganic soil carbon on gravels and determining pedon-scale variability. *Catena*. 157 436-442. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1016/j.catena.2017.06.011
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Other Conference Presentations / Papers

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- Poley, A. Glenn, N., Li, A. (2016). *Above-ground Carbon Loss from the 2015 Soda Fire.*. The Sagebrush Ecosystem Conservation: All Lands, All Hands Conference. Salt Lake City, UT. Status = PUBLISHED; Acknowledgement of Federal Support = Yes
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- Ilangakoon, N., Glenn,N,F., Spaete, L. (2015). *Characterization of low-height vegetation with waveform LiDAR.*. 57th Idaho Academy of Science and Engineering (IASE) Annual symposium, Boise State University.. . Status = OTHER; Acknowledgement of Federal Support = Yes
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- Masarik, M., K. Watson, and A. Flores. (2015). *High-resolution, intermediate range forecasting for water resource management in Southern Idaho.*. Northwest Climate Conference. Coeur d'Alene, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Lohse, K. (2017). *Improving prediction of soil carbon and fluxes at plot to landscape scales*. Eel River Team Meeting. UC Berkeley. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Walters, R., Benner, S., de Graaff, M., McNamara, J., Will, R., and A. Flores (2015). *Soil Organic Carbon in the Critical Zone: Ecohydrologic Model Sensitivity and Spin-up*. Community Surface Dynamics Modeling System Annual Meeting. Boulder, CO. Status = OTHER; Acknowledgement of Federal Support = Yes
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- Terhaar, D. (2016). *Using the chemical signature of dust to understand soil development and carbon storage in soils.*. Undergraduate Research Conference. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- Blay, E., Schwabedissen, S., Reed, S., Sheridan, P., Magnuson, T., and K. Lohse (2015). *Variation in Biological Soil Crust Bacterial Diversity with a Changing Climate*. Idaho Conference on Undergraduate Research. Boise, ID. Status = OTHER; Acknowledgement of Federal Support = Yes
- McKinnon, J. (2016). *Variations in soil pH across climatic gradients the Reynolds Creek Watershed, Idaho.*. Variations in soil pH across climatic gradients the Reynolds Creek Watershed, Idaho. . Status = OTHER; Acknowledgement of Federal Support = Yes
- Flerchinger, G.N., A.W. Fellows, and M.S. Seyfried (2016). *Water and Carbon Fluxes Along an Elevation/Precipitation Gradient in a Sagebrush Steppe Environment.*. ASA/CSSA/SSSA Annual Meeting. . Status = PUBLISHED; Acknowledgement of Federal Support = Yes
- Masarik, M., K. Watson, and A. Flores. (2016). *Weather Forecasting for Water Resource Management in Mountainous Terrain.*. Western Snow Conference. Seattle, WA. Status = OTHER; Acknowledgement of Federal Support = Yes

Other Products

- *Databases.*
  Will, Ryan M.; Benner, Shawn; Glenn, Nancy F.; Pierce, Jennifer; Lohse, Kathleen A.; Patton, Nicholas; Spaete, Lucas P.; and Stanbery, Christopher. (2017). *Mapping Soc Distribution in Semi-arid Mountainous Regions Using Variables From Hyperspectral, Lidar and Traditional Datasets* [Data set]. Retrieved from https://doi.org/10.18122/B2Q598
  Mapping SOC Distribution in Semi-arid Mountainous Regions Using Variables from Hyperspectral, Lidar, and traditional datasets

  The SOC (Soil Organic Carbon) pool is a large carbon reservoir that is closely linked to climatic drivers. In complex terrain, quantifying SOC storage is challenging due to high spatial variability. Generally, point data is distributed by developing quantitative relationships between SOC and spatially-distributed, variables like elevation. In many ecosystems, remotely sensed information on above-ground vegetation (e.g. NDVI) can be used to predict below-ground carbon stocks. With this research, we evaluated SOC variability in complex terrain and attempt to improve upon SOC models by incorporating hyperspectral and LiDAR datasets.

https://doi.org/10.18122/B2Q598

- *Databases.*
  Ilangakoon, Nayani; Glenn, Nancy F.; Spaete, Lucas P.; Dashti, Hamid; and Li, Aihua. (2016). *2014 Lidar-Derived 1m Digital Elevation Model Data Set for Reynolds Creek Experimental Watershed, Southwestern Idaho* [Data set]. Retrieved from http://doi.org/10.18122/B26C7X
  Full waveform lidar data were collected by NASA's Jet propulsion Laboratory (JPL) Airborne Snow Observatory (ASO) in August 2014 for a NASA Terretrial Ecology project (NNX14AD81G). The data were collected using a Riegl LMS Q-1560 dual laser scanner system. The full waveforms were decomposed in Riegl RiPROCESS software to generate 3D point cloud with an average point density of 14-20 pts/m^2. The point clouds were corrected for elevation and roll misalignment between adjacent flight lines in TerraScan. A Digital Elevation Model (DEM) of 1 m resolution was derived using the corrected point cloud using BCAL Lidar Tools (https://bcal.boisestate.edu/tools/lidar and https://github.com/bcal-lidar/tools/wiki/BareDEM).
- *Databases.*
  Kormos, Patrick R.; Marks, Danny; Seyfried, Mark; Havens, Scott; Hedrick, Andrew; Lohse, Kathleen A.; Masarik, Matt; and Flores, Alejandro N.. (2016). *31 Years of Spatially Distributed Air Temperature, Humidity, Precipitation Amount and Precipitation Phase From a Mountain Catchment in the Rain-snow Transition Zone* [Data set]. http://doi.org/10.18122/B2B59V
  Thirty one years of spatially distributed air temperature, relative humidity, dew point temperature, precipitation amount, and precipitation phase data are presented for the Reynolds Creek Experimental Watershed. The data are spatially distributed over a 10m Lidar-derived digital elevation model at an hourly time step using a detrended kriging algorithm. This dataset covers a wide range of weather extremes in a mesoscale basin (237 km^2) that encompasses the rain-snow transition zone and should find widespread application in earth science modeling communities. Spatial data allows for a more holistic analysis of basin means and elevation gradients, compared to point data. Files are stored in the NetCDF file format, which allows for easy spatiotemporal averaging and/or subsetting.

  Number of downloads:

- *Databases.*
  Shrestha, Rupesh and Glenn, Nancy F.. (2016). *2007 Lidar-Derived Digital Elevation Model, Canopy Height Model and Vegetation Cover Model Data Sets for Reynolds Creek Experimental Watershed, Southwestern Idaho* [Data set]. Retrieved from http://doi.org/10.18122/B27C77

  Lidar-derived raster data collected November 10-18, 2007, including digital elevation model at three (3) meters and five (5) meters; canopy height model at one (1) meter, three (3) meters and five (5) meters and vegetation cover at one (1) meter and five (5) meters.

- *Databases.*
  Eddy Covariance tower data

The Reynolds Creek CZO made its level 1 (not gap filled and modeled) eddy covariance tower data from three main core sites available via the Ameriflux network.

http://ameriflux.lbl.gov/sites/site-search/#filter-type=all&keyword=reynolds%20creek&keyword-fields=SITE_NAME%2CSITE_DESC%2CSITE_ID

Metrics: As of Sept 1, 2017, there have been 36 downloads of these data and two collaborations developed.

- *Databases.*
  Enslin, Clarissa L. ; Godsey, Sarah E. ; Marks, Danny G.; Kormos, Patrick R.; Seyfried, Mark S.; McNamara, James P.; Link, Timothy E. (2016). Data from: Hydrological and ecological observations from the rain-to-snow transition zone: a dataset for the Johnston Draw catchment, Reynolds Creek Experimental Watershed, Idaho, USA . Ag Data Commons. http://dx.doi.org/10.15482/USDA.ADC/1258769
  This data has been updated and corrected for errors. The most up to date data can be found in the dataset Data from: Eleven years of mountain weather, snow, soil moisture and stream flow data from the rain-snow transition zone - the Johnston Draw catchment, Reynolds Creek Experimental Watershed and Critical Zone Observatory, USA. v1.1

  Detailed hydrometeorological data from the mountain rain-to-snow transition zone are present for water years 2004 through 2014. The Johnston Draw watershed (1.8 km2), ranging from 1497 – 1869 m in elevation, is a sub-watershed of the Reynolds Creek Experimental Watershed (RCEW) in southwestern Idaho. The dataset includes continuous hourly hydrometeorological variables across a 372 m elevation gradient, on north- and south-facing slopes, including air temperature, relative humidity and snow depth from 11 sites in the watershed. Hourly measurements of solar radiation, precipitation, wind speed and direction, and soil moisture and temperature are available at selected stations. The dataset includes hourly stream discharge measured at the watershed outlet. These data provide the scientific community with a unique dataset useful for forcing and validating models in interdisciplinary studies and will allow for better representation and understanding of the complex processes that occur in the rain-to-snow transition zone.

- *Databases.*
  Flores, Alejandro; Masarik, Matt; and Watson, Katelyn. (2016). A 30-Year, Multi-Domain High-Resolution Climate Simulation Dataset for the Interior Pacific Northwest and Southern Idaho [Data set]. Retrieved from http://dx.doi.org/10.18122/B2LEAFD001

  Detailed hydrometeorological forcings for the broader interior Pacific Northwest region, including Reynolds Creek CZO, derived by a long-term simulation using the Weather Research and Forecasting (WRF) coupled land-atmosphere model. The simulation region consists of two nested domains. The outer domain encompasses the entire Snake River Basin at a spatial resolution of 3 km and land and atmospheric states and fluxes are captured at a temporal resolution of 1 hr. The inner domain captures RC-CZO, Dry Creek Experimental Watershed (managed by Boise State), the Boise River Basin, the Payette River Basin, and the Big Wood River Basin at a spatial resolution of 1 km. Like the outer domain, outputs are written at temporal resolutions of 1 hr. This dataset provides complete hydrometeorological forcings for the region at a spatiotemporal resolution that is not available from other products. Moreover, because it is generated with a regional weather and climate model, derived hydrometeorologic variables are serially complete (i.e., there are no temporal gaps) and internally consistent. These data provide the scientific community, and the regional modeling community in particular, with finely resolved forcings for hydrologic and ecological models, and the ability to extend fundamental advances in CZ knowledge made at RCCZO to the broader region.

- *Databases.*
  Kormos, Patrick R.; Marks, Danny G.; Boehm, Alex R.; Havens, Scott; Hedrick, Andrew; Pierson, Fred; Williams, C. Jason; Hardegree, Stuart P.; Glenn, Nancy F.; Bates, Jonathan D.; Svejcar, Anthony J. (2016). Data From: Weather, Snow, and Streamflow data from four western juniper-dominated Experimental Catchments in south western Idaho, USA.. Ag Data Commons. http://dx.doi.org/10.15482/USDA.ADC/1254010
  This data has been updated and corrected for errors. The most up to date data can be found in the dataset Data from: Eleven years of mountain weather, snow, soil moisture and stream flow data from the rain-snow transition zone - the Johnston Draw catchment, Reynolds Creek Experimental Watershed and Critical Zone Observatory, USA. v1.1

  Detailed hydrometeorological data from the mountain rain-to-snow transition zone are present for water years 2004 through 2014. The Johnston Draw watershed (1.8 km2), ranging from 1497 – 1869 m in elevation, is a sub-watershed of the Reynolds Creek Experimental Watershed (RCEW) in southwestern Idaho. The dataset includes continuous hourly hydrometeorological variables across a 372 m elevation gradient, on north- and south-facing slopes, including air temperature, relative humidity and snow depth from 11 sites in the watershed. Hourly measurements of solar radiation, precipitation, wind speed and direction, and soil moisture and temperature are available at selected stations. The dataset includes hourly stream discharge measured at the watershed outlet. These data provide the scientific community with a unique dataset useful for forcing and validating models in interdisciplinary studies and will allow for better representation and understanding of the complex processes that occur in the rain-to-snow transition zone.

- *Audio or Video Products.*
  Voice of Fire

  On August 10th, 2015, the Soda Fire started as a small wildfire in the remote Owyhee Mountains, Southwest of Boise, Idaho. High winds and temperatures and low humidity came together to create the perfect conditions for an explosive wildfire. Despite their best efforts, wildland firefighters from numerous government agencies and local municipalities could not control the fire. Voices of Fire may be the story of one fire, but it is also a larger discussion about how we manage our western landscapes moving forward to help prevent fires like this from happening again.

  The film explores the uniqueness of the Soda Fire and its effect on the people of Idaho. Many ranchers lost over 90% of their grazeable land. Without food for their cattle, many may be forced to sell all of them in an effort to survive. Numerous ranchers provide their unique stories on how the fire affected them, how they plan to cope with their losses, and their thoughts on what can be done to prevent another fire in the area.

https://www.youtube.com/watch?v=rWbeAqmcfFc&t=783s

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "A Rancher's Perspective," research and processes at Reynolds Creek. Available on YouTube at:

  https://youtu.be/YtbUyRWOl5U

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "Core Sites," research and processes at Reynolds Creek. Available on YouTube at:

  https://youtu.be/_MZELD5HDTo

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "How the CZO has helped the Agricultural Research Service" at Reynolds Creek. Available on YouTube at:

  https://youtu.be/cwpK7rJNWdI

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "Inorganic Carbon" research and processes at Reynolds Creek. Available on YouTube at:

  https://youtu.be/80zjF2sd6S4

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "Introduction," research and processes at Reynolds Creek. Available on YouTube at:

https://youtu.be/0PD1Dv0jkKA

and as part of a website virtual tour at:

https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "Measuring Carbon Storage in Sagebrush," research and processes at Reynolds Creek. Available on YouTube at:

  https://youtu.be/wbTD03-ZXaU

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "Measuring Soil Thickness across a Landscape," research and processes at Reynolds Creek. Available on YouTube at:

  https://youtu.be/1JMoRs-TAew

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "Organic Carbon," research and processes at Reynolds Creek. Available on YouTube at:

  https://youtu.be/bTYi4f4JbYk

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "Snow Modeling," research and processes at Reynolds Creek. Available on YouTube at:

  https://youtu.be/SNTdgPDsO_U

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "Taking the Pulse of the Earth using Eddy Covariance," research and processes at Reynolds Creek. Available on YouTube at:

  https://youtu.be/2rqO0GVHUDw

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "The History of Reynolds Creek." Available on YouTube at:

  https://youtu.be/n4GNNGe54WQ

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

- *Audio or Video Products.*

  Author: Hugo Sindelar

  "The Soda Fire Recovery," research and processes at Reynolds Creek. Available on YouTube at:

  https://youtu.be/uKtNsnghj3c

  and as part of a website virtual tour at:

  https://isu.maps.arcgis.com/apps/MapTour/index.html?appid=39175968604940c4934f04e15cf5a105

Other Publications

Patents

- *SOIL DEPTH MEASUREMENT SYSTEM AND METHOD*. *Patent No. 62/561,973*. UNITED STATES. Application Date = 09/22/2017.   Status = Submitted

Technologies or Techniques

Thesis/Dissertations

- Nielson, Travis. *Application of Hydrogeophysical Imaging in the Reynolds Creek Critical Zone Observatory*. (2017). Boise State University. Acknowledgement of Federal Support = Yes

- Schwabedissen SG.. *Climatic and Grazing Controls on Nitrogen Fixation by Biological Soil Crusts Utilizing a Climatic Gradient in a Semi-arid Ecosystem.*. (2016). Idaho State University. Acknowledgement of Federal Support = Yes
- Poley, Andrew. *Deriving landscape-scale vegetation cover and above ground biomass in a semi-arid ecosystem using imaging spectroscopy*. (2017). Boise State University. Acknowledgement of Federal Support = Yes
- Huber, D.. *Effects of long-term experimental manipulations of precipitation and vegetation on carbon and nitrogen dynamics in a cold desert ecosystem.*. (2017). Idaho State University. Acknowledgement of Federal Support = Yes
- Delvinne, H. *Temperature impacts on soil organic carbon decomposition across an environmental gradient in a semi-arid ecosystem*. (2016). Boise State University. Acknowledgement of Federal Support = Yes
- Tennant, C.J.. *The Sensitivity of Mountain Snowpack to Warming, PhD Dissertation, Chapter 4: The influence of elevation, aspect, and vegetation on seasonal snowpack: case studies from five mountain Critical Zone Observatory sites across the western U.S.*. (2015). Idaho State University. Acknowledgement of Federal Support = Yes
- Patton, N.R.. *Topographic Controls on Total Mobile Regolith and Total Soil Organic Carbon in Complex Terrain*. (2016). Idaho State University. Acknowledgement of Federal Support = Yes
- Enslin, C.. *Understanding the rain-to-snow transition zone: modeling snowmelt and the spatial distribution of water resources in southwestern Idaho*. (2016). Idaho State University. Acknowledgement of Federal Support = Yes

Websites

- *Reynolds Creek CZO Wiki*
  http://info.reynoldscreekczo.org/dokuwiki/doku.php?id=start

  Research within Reynolds Creek CZO is focused on answering questions about the carbon cycle. Our researchers are studying the Reynolds Creek watershed in Southwestern Idaho to better understand soil carbon dynamics. We are able to utilize decades of data and existing infrastructure from a mutually beneficial partnership with the USDA ARS.

  This wiki is home to references for collaborators working in the Reynolds Creek watershed. If you would like more information on any ongoing projects, collaborators, or data please visit our affiliated sites listed below.

- *Reynolds Creek Virtual Watershed Tour*
  http://reynoldscreekczo.org/wordpress/
  The Reynolds Creek Virtual Tour (ReVRT) strives to share the research being conducted at the Reynolds Creek Critical Zone Observatory (CZO) with local stakeholders and the broader public through a virtual tour of the watershed.

  Reynolds Creek Experimental Watershed was established in 1960 by the USDA ARS to support research addressing water supply, seasonal snow, soil freezing, water quality, and hydrology in semi-arid rangelands of the interior Pacific Northwest. In 2013, the NSF Reynolds Creek Critical

Zone Observatory was established in partnership with the USDA ARS Northwest Research Center. This Virtual Watershed Tour introduces the public, students and researchers to the research being conducted at the Reynolds Creek CZO and its history. The ReVRT will provide scientists at RCCZO with a tool to help local stakeholders and the broader public understand their research.

Back to the top

Participants/Organizations

Research Experience for Undergraduates (REU) funding

Form of REU funding support:
REU supplement

How many REU applications were received during this reporting period?
0

How many REU applicants were selected and agreed to participate during this reporting period?
0

REU Comments:
N/A

What individuals have worked on the project?

Lohse, Kathleen	PD/PI
Benner, Shawn	Co PD/PI
Flores, Alejandro	Co PD/PI
Glenn, Nancy	Co PD/PI
Seyfried, Mark	Co PD/PI
Crosby, Benjamin	Co-Investigator
Finney, Bruce	Co-Investigator
Flerchinger, Gerald	Co-Investigator
Garen, David	Co-Investigator
Godsey, Sarah	Co-Investigator

Marks, Danny	Co-Investigator
Pierce, Jennifer	Co-Investigator
Aho, Ken	Faculty
Baxter, Colden	Faculty
Cadol, Daniel	Faculty
Chandler, David	Faculty
de Graaff, Marie-Anne	Faculty
Feris, Kevin	Faculty
Holbrook, W. Steven	Faculty
Kohn, Matthew	Faculty
Link, Timothy	Faculty
Magnuson, Timothy	Faculty
Pomeroy, John	Faculty
Reinhardt, Keith	Faculty
Fellows, Aaron	Postdoctoral (scholar, fellow or other postdoctoral position)
Kormos, Patrick	Postdoctoral (scholar, fellow or other postdoctoral position)
Masarik, Matt	Postdoctoral (scholar, fellow or other postdoctoral position)
Watson, Katelyn	Postdoctoral (scholar, fellow or other postdoctoral position)
Zhou, Qingtao	Postdoctoral (scholar, fellow or other postdoctoral position)
McCorkle, Emma	Other Professional
Parsons, Susan	Other Professional

Reed, Sasha	Other Professional
VanVactor, Steven	Other Professional
Patton, Nicholas	Technician
Clark, Patrick	Staff Scientist (doctoral level)
Goodrich, David	Staff Scientist (doctoral level)
Aguayo, Miguel	Graduate Student (research assistant)
Commendador, Amy	Graduate Student (research assistant)
Dashti, Hamid	Graduate Student (research assistant)
Delvinne, Hasini	Graduate Student (research assistant)
Gossner, Kayla	Graduate Student (research assistant)
Huber, David	Graduate Student (research assistant)
Ilangakoon, Nayani	Graduate Student (research assistant)
Nielson, Travis	Graduate Student (research assistant)
Radke, Anna	Graduate Student (research assistant)
Sharma, Harmandeep	Graduate Student (research assistant)
Vega, Samantha	Graduate Student (research assistant)
Will, Ryan	Graduate Student (research assistant)
Spaete, Lucas	Non-Student Research Assistant
Bruck, Benjamin	Undergraduate Student
Holloway, Mariah	Undergraduate Student
Johnson, Joel	Undergraduate Student

King, Remington	Undergraduate Student
Rangel, Ivan	Undergraduate Student
Refaey, Dylan	Undergraduate Student
Youngblood, Peter	Undergraduate Student
Perdrial, Julia	Consultant
Blay, Erika	Other
Clark, Martyn	Other
Cram, Zane	Other
Galanter, Amy	Other
McNamara, James	Other
Niemeyer, Ryan	Other
Schwabedissen, Stacy	Other
Stanbery, Christopher	Other
Weppner, Kerrie	Other
Williams, Jason	Other

Full details of individuals who have worked on the project:

Kathleen A Lohse
Email: klohse@isu.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 5
Contribution to the Project: Lohse oversaw all aspects of the CZO. She worked with researchers on research questions to he administrative aspects, such as annual progress reports and the budget; and served as the principal contact with NSF and othe the expansion of the CZO's research program to include new projects and adapt to new research directions. Dr. Lohse travelle Geophysical Union meeting, fall PI meeting, and All Hands Meeting. Lohse worked with the database manager to create web

scientific community in CZO activities and external engagement for a community resource. Lohse advised 3 students and was
Funding Support: Reynolds Creek CZO, Idaho State University
International Collaboration: No
International Travel: No

Shawn Benner
Email: sbenner@boisestate.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 3
Contribution to the Project: Surface soil organic carbon mapping and advised Ryan Will
Funding Support: RC CZO, Boise State University
International Collaboration: No
International Travel: No

Alejandro Flores
Email: lejoflores@boisestate.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 3
Contribution to the Project: Priority 3: Integrated modeling
Funding Support: NSF RC CZO, NASA TE, NSF CAREER, NSF WAVE
International Collaboration: No
International Travel: No

Nancy F Glenn
Email: nancyglenn@boisestate.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 4
Contribution to the Project: Remote sensing at CZO, collaboration with NASA TE activities
Funding Support: NASA TE, Boise State
International Collaboration: No
International Travel: No

Mark S Seyfried
Email: mark.seyfried@ars.usda.gov
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 6
Contribution to the Project: Coordinated and facilitated field projects at RCEW as deputy director and collaborated on bulk
Funding Support: USDA ARS
International Collaboration: No
International Travel: No

Benjamin T Crosby
Email: crosby@isu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2
Contribution to the Project: Advise Nick Patton on LiDAR and geomorphic observations
Funding Support: Idaho State University
International Collaboration: No
International Travel: No

Bruce P Finney
Email: finney@isu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1
Contribution to the Project: I run the ISU stable isotope lab and facilitate analysis and interpretation of some of the stable is
Funding Support: in kind
International Collaboration: No
International Travel: No

Gerald N Flerchinger
Email: gerald.flerchinger@ars.usda.gov
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 6
Contribution to the Project: Selecting core sites, coordinating activities at the core sites and setting up eddy covariance syst
Funding Support: USDA-ARS and Reynolds Creek CZO grant.
International Collaboration: No
International Travel: No

David C Garen
Email: David.Garen@por.usda.gov
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 1
Contribution to the Project: Assisting ARS on developing spatial meteorological forcings
Funding Support: Regular USDA-NRCS salary
International Collaboration: No
International Travel: No

Sarah E Godsey
Email: godsey@isu.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 3
Contribution to the Project: Supervised Clarissa Enslin's MS project on rain-snow transition data and modeling in the Johns

chemistry contributions to Reynolds Mtn E stream.
Funding Support: NSF Tri-state EPSCoR Track II - WC-WAVE and RCCZO
International Collaboration: No
International Travel: No

Danny G Marks
Email: ars.danny@gmail.com
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 6
Contribution to the Project: Developing spatially continuous model forcing data for the RCCZO; working toward a 30 yr da
deposition, redistribution, melt, soil moisture, streamflow for RCCZO.
Funding Support: USDA-ARS
International Collaboration: Yes, Canada
International Travel: No

Jennifer L Pierce
Email: jenpierce@boisestate.edu
Most Senior Project Role: Co-Investigator
Nearest Person Month Worked: 2
Contribution to the Project: 1) Soil Inorganic Carbon (SIC) lead: primary advisor for Chris Stanbery, who is measuring and
employees in the soils lab preparation and analysis of soils carbon (organic and inorganic). 3) Currently coordinating and lead
Funding Support: NSF CZO, Murdock Foundation
International Collaboration: No
International Travel: No

Ken Aho
Email: kenaho1@gmail.com
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Contributed to statistical analyses on numerous manuscripts and attended biogeochemistry mee
Funding Support: ISU
International Collaboration: No
International Travel: No

Colden V Baxter
Email: baxtcold@isu.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: I am a investigator and collaborator on in-stream focused ecological studies at the Reynolds Cr
Research and Education, which is a partner organization with the CZO.
Funding Support: I have not yet received any funding support for research as part of the CZO.

International Collaboration: No
International Travel: No

Daniel Cadol
Email: dcadol@nmt.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Collaborating on black carbon quantification at JRB and RC CZO
Funding Support: NSF
International Collaboration: No
International Travel: No

David G Chandler
Email: dgchandl@syr.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Continuous investigation of snowpack and soil moisture response to changing climate and pres
on near surface soil organic carbon mass percent and functional type, and the related controls on soil water repellency and uns
Funding Support: Syracuse University
International Collaboration: No
International Travel: No

Marie-Anne de Graaff
Email: marie-annedegraaff@boisestate.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2
Contribution to the Project: Overall Objective: Understand how soil organic carbon input affects soil structure and carbon c
characters affect the response of soil organic carbon (SOC) decomposition to climate change.
Funding Support: CZO and BSU
International Collaboration: No
International Travel: No

Kevin P Feris
Email: kevinferis@boisestate.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Assisted with soil collections for microbial analysis and served on committee
Funding Support: NSF, USDA, DOE, INL
International Collaboration: No
International Travel: No

W. Steven Holbrook
Email: steveh@uwyo.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: In August 2015, we acquired geophysical data (seismic refraction, electrical resistivity, ground-
induction) in several sub-watersheds of RCCZO (Reynolds Mountain, Upper Sheep Creek, Upper Johnston Draw), in collabo
Track 1 grant, and the RCCZO grant (through Dr. Lohse). We will analyze and interpret the collected data together with our F
Funding Support: NSF-EPSCoR Track 1 grant to the University of Wyoming, and the RCCZO grant (through Dr. Lohse).
International Collaboration: No
International Travel: No

Matthew J Kohn
Email: mattkohn@boisestate.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Developing stable isotope tools for understanding interactions among hydrologic cycle, soils ar
Funding Support: Boise State University
International Collaboration: No
International Travel: No

Timothy E Link
Email: Tlink@uidaho.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Coordinating work funded by other programs with CZO goals.
Funding Support: NSF-IGERT, NSF-CBET
International Collaboration: No
International Travel: No

Timothy Magnuson
Email: magntimo@isu.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2
Contribution to the Project: I served as a Co-advisor for Ms. Stacy Schwabedissen (MS Microbiology, Idaho State Universi
University, May 2016) on her undergraduate CZO research project. I am a co-author on 3 submitted publications from these s
Funding Support: I received no direct funding from the CZO grant. I am funded by NASA (Exobiology and Astrobiology, 2
Laboratory-Pacific Northwest National Laboratory.
International Collaboration: No
International Travel: No

John Pomeroy

Email: john.pomeroy@usask.ca
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Modelling Reynolds Creek with Cold Regions Hydrological Model for snow process climate se
catchments as part of long term collaboration with USDA ARS
Funding Support: Natural Sciences and Engineering Research Council of Canada funding through Discovery Grants and the
International Collaboration: Yes, Canada, China, Germany, Spain, Switzerland, United Kingdom
International Travel: No

Keith Reinhardt
Email: reinkeit@isu.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2
Contribution to the Project: We are in charge of installing and monitoring tree and shrub water relations. This includes sap
Funding Support: NSF-CZO, ISU
International Collaboration: No
International Travel: No

Aaron W Fellows
Email: afellowswork@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: Contributing to Priority 2: Environmental monitoring network by reprocessing historic eddy co
Funding Support: CZO
International Collaboration: No
International Travel: No

Patrick R Kormos
Email: pkormos.fs@gmail.com
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 8
Contribution to the Project: Spatial distribution of temperature, humidity, and precipitation data over the RCZO, including
tours. Represent the RCZO at the IMLCZO summer modeling workshop.
Funding Support: ARS and CZO
International Collaboration: No
International Travel: No

Matt Masarik
Email: mattmasarik@boisestate.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12

Contribution to the Project: Modeling with WRF
Funding Support: NSF, NASA
International Collaboration: No
International Travel: No

Katelyn Watson
Email: katelynwatson@boisestate.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: Matt Masarik and I have been developing weather and climate datasets that include the CZO ar
preliminary data processing for an eddy covariance tower deployed in the Dry Creek Experimental Watershed.
Funding Support: NASA, Other grants, BSU dept. funding
International Collaboration: No
International Travel: No

Qingtao Zhou
Email: qingtaozhou@boisestate.edu
Most Senior Project Role: Postdoctoral (scholar, fellow or other postdoctoral position)
Nearest Person Month Worked: 12
Contribution to the Project: I mainly focusing on data analysis on remote sensing data and eddy flux data for RCEW using
net ecosystem exchange estimates over RCEW.
Funding Support: NASA, NSF
International Collaboration: No
International Travel: No

Emma Paige McCorkle
Email: mccoemma@isu.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 12
Contribution to the Project: Water biogeochemistry, soil biogeochemistry, field and lab manager-ish, archive master,
Funding Support: RC CZO
International Collaboration: No
International Travel: No

Susan B Parsons
Email: parssusa@isu.edu
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 6
Contribution to the Project: I am a data manager, collaborating with Steven VanVactor at the USDA-ARS and Luke Spaete
efforts. Additionally, I am registering data with the main CZO metadata portal, and managing content on the Reynolds Creek
purpose of hosting and serving-out Reynolds Creek CZO data and research products.

Funding Support: Reynolds Creek CZO and NSF/EPSCoR Managing Idaho Landscapes for Ecosystem Services (MILES)
International Collaboration: No
International Travel: No

Sasha C Reed
Email: screed@usgs.gov
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 1
Contribution to the Project: I am working with Kitty Lohse and her graduate student on an N2 fixation study.
Funding Support: USGS
International Collaboration: No
International Travel: No

Steven VanVactor
Email: steven.vanvactor@ars.usda.gov
Most Senior Project Role: Other Professional
Nearest Person Month Worked: 6
Contribution to the Project: As the database manager for the NWRC I have ongoing data collection and management respo
through funding from CZO are included in our telemetered network so I will also collect and manage data from those sites. I i
Creek Experimental Watershed sites that is used to support the Reynolds Creek CZO data discovery. The information windov
to data available from each site, and experimental graphs of data collected daily from the site to use in site performance diagn
same information that was included in Google Maps. Google Earth allows a greater scale so that more sites can be visualized
datasets are available now. All of these resources will be incorporated into a Reynolds Creek CZO website when a local web
Funding Support: USDA-ARS
International Collaboration: No
International Travel: No

Nicholas R Patton
Email: Pattnich@isu.edu
Most Senior Project Role: Technician
Nearest Person Month Worked: 6
Contribution to the Project: Determining total mobile regolith thickness and soil carbon pools on the pedon to watershed sc
Funding Support: RC CZO ISU CERE
International Collaboration: No
International Travel: No

Patrick E Clark
Email: pat.clark@ars.usda.gov
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 6
Contribution to the Project: Assessment of vegetation status and response to livestock grazing, fire and other landscape-sca

diversity, and production (ANPP).
Funding Support: ARS
International Collaboration: No
International Travel: No

David Goodrich
Email: dave.goodrich@ars.usda.gov
Most Senior Project Role: Staff Scientist (doctoral level)
Nearest Person Month Worked: 1
Contribution to the Project: Participation in conference calls and planning to evaluate a watershed hydrology and erosion m
CZO as a result of the 2015 Soda fire.
Funding Support: USDA-ARS base funding
International Collaboration: No
International Travel: No

Miguel Aguayo
Email: miguelaguayo@boisestate.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Hillslope scale hydrologic modeling on basins around Reynolds Creek CZO (i.e. Dry Creek Ex
Funding Support: Tri-State WC-WAVE
International Collaboration: No
International Travel: No

Amy S Commendador
Email: commamy@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: As part of the CZO I will be examining processes that affect stable isotope (primarily carbon ar
gradient, holding all other state factors constant. The goal is to better understand the effect of climate on these compositions, a
of my dissertation I will be collecting soil, plant and faunal samples from across an environmental gradient for various C and
Funding Support: RC-CZO ISU for sample analyses, Idaho State University
International Collaboration: No
International Travel: No

Hamid Dashti
Email: hamiddashti@u.boisestate.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Estimation of Leaf Area Index (LAI) of dryland shrubs using hyperspectral data
Funding Support: NASA, NSF

International Collaboration: No
International Travel: No

Hasini H Delvinne
Email: hasinidelvinne@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 1
Contribution to the Project: Completing Assessing the temperature sensitivity of soil organic carbon pools and the impact o
Funding Support: Funded as PHD at ASU but completing outstanding products from RC CZO
International Collaboration: No
International Travel: No

Kayla Gossner
Email: gloskayl@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 7
Contribution to the Project: Analyzing particulate organic carbon and nutrients in stream water
Funding Support: RC CZO ISU GTA
International Collaboration: No
International Travel: No

David P Huber
Email: hubedavi@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Analyzing data examining long-term responses to altered precipitation,vegetation and soil thick
Funding Support: ISU Doctor of Arts Teaching Fellowship (2 yrs) ISU CPI USGS Youth Internship Program RC CZO sum
International Collaboration: No
International Travel: No

Nayani Ilangakoon
Email: nayaniIlangakoon@u.boisestate.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Derive rangeland ecosystem variables from airborne small footprint waveform lidar attributes
Funding Support: NASA TE, BSU
International Collaboration: No
International Travel: No

Travis Nielson
Email: travisnielson@u.boisestate.edu

Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 8
Contribution to the Project: 1) The use of time-lapse 3D electrical resistivity tomography, at the core-sites, to image change
precipitation events. 2) Seismic refraction tomography survey of Johnston Draw to map the deep critical zone architecture as
Funding Support: RC CZO
International Collaboration: No
International Travel: No

Anna G Radke
Email: radkanna@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: Installation of lysimeters, soil moisture probes, soil matric potential probes, and piezometers in
transport.
Funding Support: RC CZO ISU TA
International Collaboration: No
International Travel: No

Harmandeep Sharma
Email: sharharm@isu.edu
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: I have collected diurnal gas exchange data this summer in three sagebrush communities and su
Funding Support: NSF CZO
International Collaboration: No
International Travel: No

Samantha Vega
Email: sam.vega@ars.usda.gov
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 12
Contribution to the Project: • Installed silt fence study within Murphy Creek in order to monitor hillslope to watershed scal
Soda fire. • Collected vegetation recovery data and soil water repellency immediately after the fire, 2016, and 2017. • Collect
Funding Support: USDA ARS
International Collaboration: No
International Travel: No

Ryan M Will
Email: Rmwill139@gmail.com
Most Senior Project Role: Graduate Student (research assistant)
Nearest Person Month Worked: 9

Contribution to the Project: Field sampling of soils for SOC analyses. Mapping sample sites with RTK GPS. Laboratory an
and predictor variables derived from remote sensing data.
Funding Support: NSF
International Collaboration: No
International Travel: No

Lucas P Spaete
Email: lucasspaete@boisestate.edu
Most Senior Project Role: Non-Student Research Assistant
Nearest Person Month Worked: 4
Contribution to the Project: BSU data managment
Funding Support: Boise State University
International Collaboration: No
International Travel: No

Benjamin Bruck
Email: benjaminbruck@u.boisestate.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked:
Contribution to the Project: soil sample processing
Funding Support: CZO
International Collaboration: No
International Travel: No

Mariah Holloway
Email: mariahholloway@u.boisestate.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked:
Contribution to the Project: soil sample processing
Funding Support: CZO
International Collaboration: No
International Travel: No

Joel Johnson
Email: joel.dlcruz.johnson@gmail.com
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked:
Contribution to the Project: Crunched data for the colluvium traps project, and worked underneath Clay and Dr Pierce digg
Funding Support: Under Dr Pierce, as well as the LSAMP REU from Boise State
International Collaboration: No
International Travel: No

Remington King
Email: kingremi@isu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked: 5
Contribution to the Project: soil and water sample processing
Funding Support: CZO
International Collaboration: No
International Travel: No

Ivan Rangel
Email: rangivan@isu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked:
Contribution to the Project: Helped graduate students in their data collection at Reynolds Creek
Funding Support: MURI program
International Collaboration: No
International Travel: No

Dylan Refaey Refaey
Email: refadyla@isu.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked:
Contribution to the Project: soil sample processing
Funding Support: CZO
International Collaboration: No
International Travel: No

Peter Youngblood
Email: peteryoungblood@u.boisestate.edu
Most Senior Project Role: Undergraduate Student
Nearest Person Month Worked:
Contribution to the Project: soil sample processing
Funding Support: CZO
International Collaboration: No
International Travel: No

Julia N Perdrial
Email: Julia.Perdrial@uvm.edu
Most Senior Project Role: Consultant
Nearest Person Month Worked: 2
Contribution to the Project: Analysis of dissolved organic matter with absorbance and fluorescence spectroscopy

Funding Support: none
International Collaboration: No
International Travel: No

Erika Blay
Email: blayerik@isu.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: Completed analyses and manuscript after graduation
Funding Support: N/A
International Collaboration: No
International Travel: No

Martyn P Clark
Email: mclark@ucar.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: Collaborating with USDA ARS on existing projects
Funding Support: NSF, Bureau of Reclamation, US Army Corps of Engineers, NOAA
International Collaboration: Yes, Austria, United Kingdom
International Travel: No

Zane K Cram
Email: zane.cram@ars.usda.gov
Most Senior Project Role: Other
Nearest Person Month Worked: 6
Contribution to the Project: I manage the Reynolds Creek Experimental Watershed and all field projects associated with the
Funding Support: USDA-ARS NWRC hard funding
International Collaboration: No
International Travel: No

Amy E Galanter
Email: agalante@nmt.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: Analyzing Jemez CZO soils for black carbon concentration as part of studying impacts of wildf
Funding Support: EPSCoR, WRRI
International Collaboration: No
International Travel: No

James P McNamara

Email: jmcnamar@boisestate.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: I collaborate with Danny Marks, Mark Seyfried and others on existing projects. Our primary re
Funding Support: NSF, NASA, NOAA
International Collaboration: No
International Travel: No

Ryan J Niemeyer
Email: niem3790@vandals.uidaho.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: -completed manuscripts
Funding Support: National Science Foundation's IGERT program (Award 0903479) - ended in January 2015, U of Idaho
International Collaboration: No
International Travel: No

Stacy G Schwabedissen
Email: kingstac@isu.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: Completing analyses and manuscripts examining N fixation, which is strongly coupled to C cy
Funding Support: N/A
International Collaboration: No
International Travel: No

Christopher A Stanbery
Email: chrisstanbery@u.boisestate.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 2
Contribution to the Project: Revising manuscripts for submission.
Funding Support: RC CZO, BSU
International Collaboration: No
International Travel: No

Kerrie Weppner
Email: kerrieweppner@boisestate.edu
Most Senior Project Role: Other
Nearest Person Month Worked: 1
Contribution to the Project: Soil sample processing
Funding Support: CZO and volunteer

International Collaboration: No
International Travel: No

Jason C Williams
Email: jason.williams@ars.usda.gov
Most Senior Project Role: Other
Nearest Person Month Worked: 2
Contribution to the Project: Already working at USDA-ARS Northwest Watershed Research Center on various projects at I
Funding Support: USDA-ARS
International Collaboration: No
International Travel: No

What other organizations have been involved as partners?

Bureau of Land Management	Other Organizations (foreign or domestic
NCAR	Other Organizations (foreign or domestic
NRCS	Other Organizations (foreign or domestic
USDA ARS	Other Organizations (foreign or domestic
USGS	Other Organizations (foreign or domestic
University of Idaho	Academic Institution
University of Illinois, Urbana Champagne	Academic Institution

Full details of organizations that have been involved as partners:

Bureau of Land Management
Organization Type: Other Organizations (foreign or domestic)
Organization Location: Boise, Idaho
Partner's Contribution to the Project:
Personnel Exchanges
More Detail on Partner and Contribution:

NCAR

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Boulder, CO
Partner's Contribution to the Project:
Collaborative Research
More Detail on Partner and Contribution:

NRCS
Organization Type: Other Organizations (foreign or domestic)
Organization Location: Portland, Oregon
Partner's Contribution to the Project:
Collaborative Research
Personnel Exchanges
More Detail on Partner and Contribution:

USDA ARS
Organization Type: Other Organizations (foreign or domestic)
Organization Location: National
Partner's Contribution to the Project:
Financial support
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges
More Detail on Partner and Contribution:

USGS
Organization Type: Other Organizations (foreign or domestic)
Organization Location: Moab, Utah
Partner's Contribution to the Project:
Collaborative Research
Personnel Exchanges
More Detail on Partner and Contribution:

University of Idaho
Organization Type: Academic Institution
Organization Location: Moscow, Idaho
Partner's Contribution to the Project:
Facilities
Collaborative Research
Personnel Exchanges
More Detail on Partner and Contribution:

University of Illinois, Urbana Champagne
Organization Type: Academic Institution
Organization Location: Urbana Champagne, IL
Partner's Contribution to the Project:
In-Kind Support
Collaborative Research
More Detail on Partner and Contribution:

What other collaborators or contacts have been involved?

Drs. Katherine Renwick and Ben Poulter, University of Montana, NASA Maryland

Dr. Robert Jackson, Stanford University

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Impacts

What is the impact on the development of the principal discipline(s) of the project?

Critical Zone Science The Reynolds Creek CZO seeks to foster the development of Critical Zone Science as discipline that integrates across disciplines and fields to understand the critical zone, the surface skin of the earth that extends from the top of the tree canopy to the lower limits of the groundwater. CZOs provide a platform to conduct interdisciplinary to transdisciplinary science by integrating across geological, soil, hydrologic, ecological, and social sciences to understand the critical zone. The emergence of the CZO observatories and Network brings the ability to test hypotheses and ask questions across broad environmental conditions and gradients that could not be achieved with single principle-investigator funding efforts.

Critical Zone Science as a discipline is motivated and adds value to earth system science by addressing research gaps that occur at the interface between disciplines, across space and deep time scales, and multiple dimensions. For example, the Reynolds Creek CZO seeks to understand the role of soil environmental variables such as soil moisture and depth that vary across complex terrain in governing soil carbon storage and turnover in a semi-arid environment. For this reason, soil samples are being collected to depth of bedrock or refusal. Other networks and agencies quantifying soil carbon such as the NCAP, NEON and NRCS are measuring soil carbon to 30 cm depth in the case of NEON and 1 m depth in the case of NRCS and NCAP. These efforts may capture the variability in soil surface carbon, which is likely to be the most sensitive to land use and climate change, but may also likely overlook and vastly underestimate the total stores of carbon on the landscape. Another example of where Reynolds Creek CZO is contributing to a gap in the carbon cycle is through the quantification of inorganic carbon associated with rocks. Soil inorganic carbon stores are significant in arid and semi-arid regions, and pedogenic carbonate often follows a morphogenetic development sequence where carbonates coat rocks, form masses and nodules and eventually may become engulfted and cemented (NRCS manual). The inorganic carbon associated with these carbonate coatings associated with rocks and masses are not typically quantified by soil scientists because they are greater than 2 mm in size, the operational definition of soil and they are difficult to measure owing to the heterogeneity and scale. Consequently, soil inorganic carbon may be vastly underestimated in arid and semi-arid regions. As part of the RC CZO, rocks with carbonate coatings are being pulverized to quantify bulk inorganic carbon. Our analyses are showing that in some cases, rock carbonate coating can represent as much as 43% of total inorganic carbon in soil profiles.

Soil carbon and land surface modeling Recent studies have identified major gaps in model-data agreement with present-day soil carbon stocks and indicated that improving empirical data sets, model driving variables, and model parameterization could substantially increase model–data agreement. We are bridging the gap between empirical field studies that are conducted at plot scales and models attempted at regional and global soil scales to make advancements in soil C research and modeling efforts and producing an extensive intermediate-scale or landscape scale dataset of soil carbon (C) and associated environmental variables as a part of the RC CZO. These datasets will be used initially to evaluate predictions of soil carbon based on the initial calibration of the land surface-vegetation model used as part of RC CZO. However, we anticipate these sites will be used in combination with our landscape soil dataset by other carbon and global climate modelers to test model prediction. Our monitoring network efforts will produce the minimum set of process measurements that will be critical for landscape level model calibration. The modeling activities from the RC CZO science will yield benchmark datasets that will have broad impact and importance to the ecohydrologic and biogeochemical modeling community. These include a highly spatiotemporally resolved (order 10^0-10^1 m in space, hourly in time) environmental forcing dataset can be used as input to a wide array of ecohydrologic and biogeochemical models. This dataset will serve as an important vehicle to build collaborations with researchers from other CZOs and the broader community. This will allow us to contribute to continued advances in biophysical and biogeochemical modeling.

What is the impact on other disciplines?

Historical datasets of rainfall, stream flow, evaporation, and soil moisture (30 years, 10-24 sites depending on datastream) available on criticalzone.org can be used by hydrologist, landscape evolution, atmospheric scientists and other disciplines. The highly spatiotemporally resolved (order 10^0-10^1 m in space, hourly in time) environmental forcing modeled datasets are also being made available via criticalzone.org website and other avenues to land surface modelers, and regional to global climate modelers to be used as input to a wide array of land surface, regional and global climate models. These, the landscape soil dataset, and environmental network, datasets will provide improved empirical data sets, model driving variables and parameterization to increase model-data agreement.

What is the impact on the development of human resources?

We supported research and/or salary (partial, summer, and/or full) for 10 graduates students (50% women), 2 postdoctoral associates, 9 undergraduates, 5 high school students, 1 high school teacher during year 2 of RC CZO through a combination of diversified funding sources (ISU and BSU teaching assistantships, collaborations, grant funding). Another set of graduate students (5 at BSU) and postdocs (2 at BSU, 1 ISU part-time) are aligned with the Reynolds Creek CZO (salary not funded by CZO but enabled by investments in CZO) (total 21 graduate students, 4 postdocs). Most post-docs, graduate students and undergraduates work with several of the Reynolds Creek CZO PIs whose expertise range across geoscience, soil science, plant sciences, microbiology, hydrology, plant physiological ecology, stream ecology and geomorphology. Students freely interact across departments and universities and agencies (Idaho State University, Boise State University, and USDA ARS), and this training promotes the development of a critical mass of critical zone scientists. We continue to expand our campaign to diversify our funding sources for graduate training given that most of our graduate assistant funding ends in year 4 owing to the 50% reduction in the original budget. Two MS theses, one 1PhD thesis, and one undergraduate manuscript were completed in YR 4 (ISU: PhD, Huber, undergraduate Blay; BSU: Will, Nielsen) with >20 papers in review and 24 published in yr 4.

What is the impact on physical resources that form infrastructure?

Vehicles

The terrain and road conditions at the RC CZO are such that four-wheel drive vehicles or ATV's are required for access to most of the research sites. These are generally supplied, free of charge, to CZO participants by the ARS. The annual wear and tear is considerable, resulting in about a $10,000 dollar cost to the ARS.

Base Station

Glenn (co-PI) and Seyfried worked with Bonneville Blueprint to facilitate installation of GPS base station located at the RCEW headquarters (Quonset) (Bonneville Blueprint provided all labor and equipment). This base station will improve collection of GPS and RTK GPS data. Through collaboration with NASA TE, one radio was purchased to be a roving radio to broadcast signal across watershed to receive RTK GPS data. Another radio is being purchased on the BSU CZO subcontract to broadcast signal across the watershed. Rather than spending 2-3 hours at each site positioning the RTK for collection, data can be collected immediately and then on-the-fly RTK GPS positions can be determined in the field.

Radios

ARS purchased an additional 5 radios for communicating in the watershed. This additional infrastructure adds additional safety for participants in the field.

Road improvements

The middle (private) road of the Reynolds Creek CZO has been vastly improved by the ARS personnel over the past year of the CZO project and this improvement has facilitated and added additional safety for participants in their field activities. The East side road of Reynolds remains problematic and experienced a gully washer in July that resulted in the degradation of the road even further. Conversations with the BLM have been initiated to promote improvement of these roads and recent road improvements are underway.

Range Building at Reynolds Creek CZO

The ARS projects to complete minor renovations on the Range Building by December to improve the kitchen and shower facilities for overnight visitors. In particular, these renovations include adding an additional shower and bathroom to the range building as well as adding a kitchen area with sink and stovetop burners (electric or other safe models). Lohse, Seyfried, and Pierson are writing a NSF proposal due January for improvement of the facilities to include more and better dorm space for visitors and outreach education center.

Automated water chemistry sensors

Early in 2015, ARS experienced a loss in personnel due to sickness and the funding for this person (~$50k) came back to the ARS in terms of salary. ARS moved the current CZO research technician line to this ARS line (also see changes). In lieu of this salary savings on CZO budget, PIs and EC agreed that purchase of a nested set of equipment for automated sensors for surface water chemistry to quantify stream material export and capture the fire response following a prescribed burn would be the most beneficial use of these funds. In June, we obtained 3 Hach OTT automated water sensors with temperature, pH, oxygen, conductivity, and two anion select electrodes (chloride and nitrate) in addition to three Turner Design C3 sensors for turbidity, temperature, colored dissolved organic matter (CDOM), and rhodamine dye tests. At the end of June, these sensors were all deployed temporarily in three positions within Reynolds Creek: Johnson Draw, Dobson Creek, and Reynolds Creek (at Tollgate). Permanent, long-term infrastructure (rock cages for Tollgate) were completed by October 2016. New permanent positions proposed based on August 2015 Soda Fire are now Johnson Draw, Reynolds Creek (at Tollgate) and now at Murphy Creek and Outlet after Aug 2015 fire (Soda Fire). Murphy Creek weir and housing were restored.

Permitting

Pierson and ARS continue discussions with the BLM and Shoshone-Paiute Tribe with regards to permitting the juniper selected site as a CORE site and getting permission to install the eddy covariance systems and other instruments as part of the CORE site at this location. This location has historical and cultural importance to the Shoshone-Paiute Tribe in this region.

What is the impact on institutional resources that form infrastructure?

Memorandum of Understanding (ARS and ISU and ARS and BSU)

Lohse (ISU), Flores (BSU), Seyfried and Pierson with the ARS established a MOU between ISU and ARS and also BSU and ARS as part of the understood CZO partnership. Signed March 2015.

Data policy agreement between ISU, ARS, and BSU

- ISU, ARS, and BSU established a data policy document for the Reynolds Creek CZO
- This document has been posted to the Reynolds Creek wiki site.

Vertically integrated data management (from cradle [field collection] to grave [archive or BORG like ODM2]

- Vertically Integrated Templates have been developed and posted to Reynolds Creek wiki such that raw data can be collected in excel spreadsheet spreadsheets that are YODA and ultimately ODM2 compatible and compliant. These resources can be used by investigators so that they do not have to transfer data from one spreadsheet to another and metadata is conserved.

What is the impact on information resources that form infrastructure?

Coordination and policy development activities:

- Coordination activities included working with the USDA ARS, national CZO data management group, and RC-CZO participants and students. We worked with the USDA ARS to establish a Memorandum of Understanding (MOU) and policy standards to accomplish the RC-CZO data management needs while also leveraging the long-term ongoing data management at ARS (March 2015). We attended the face-to-face IMG CZO data meeting and coordinated with the national CZO data management team to adhere and contribute to national CZO data management.
- We developed protocols and provided training to coordinate the RCCZO participants to ensure data are properly managed (including archival), as well as provided training opportunities to students for data management. We established a Wiki to be transparent in our protocols and share cross CZOs.
- Policy development activities included developing a data sharing policy and standards for data formats and metadata. A data sharing policy was developed by the EC, based on successful research data policies used by the EC on other research projects. The data sharing policy outlines the agreement to share data by investigators and collaborators who receive material or logistical support. The policy outlines the timeline for sharing data, along with proper acknowledgement. Data created by the project are being stored in a combination of formats that are appropriate for near-term use and long-term archival storage and metadata standards (such as ISO 19115-2) were agreed upon by the EC and set as a standard for all data ingested into data storage.

Data service and management activities:

- Data services activities included developing data access and sharing mechanisms, and archiving and preserving data. The RC CZO is managing its data locally through our data management staff and scientists, in collaboration with USDA ARS, but make the data broadly available through the national CZO and other regional and national portals. A data management strategy and schematic is being developed to demonstrate how the data will be posted for public consumption on a website with geospatial services. Data management to provide single location file storage, redundant file archiving, and web service maintenance are being addressed. The data is following the national CZO data format such that it can be harvested and made available on the national central CZO data portal or other available network agreed upon by the national CZO.
- We established a cloud server as part of Reynolds Creek CZO

- We established a website for easy posting of metadata for RC CZO data
- http://www.lohselab.com/rcew-czo-metadata.html
- We established an internal Wiki to post protocols and then are working to establish a mechanism to post protocols across CZOs.
- We established and posted specimen and time series, vertically-integrated templates as EXCEL spreadsheets that can be used collect and organize field data and meta data that can then be easily converted to YODA files to be digested by ODM2
- We established GIS web services as part (http://gis.reynoldscreekczo.org/arcgis/rest/services)
- Cyber-infrastructure research activities include extending our datasets and services to collaborating computer scientists and others interested in Big Data methodologies.

What is the impact on technology transfer?

We produced 24TB of data as part of the fine-resolution forcing model output data. These data include hourly, 10 m resolution rasterized data, 30 yr record of radiation, temperature, precipitation generated from historic climate datasets for 239 km^2 of Reynolds Creek Experimental Watershed (45 TB of data) using detrended kriging methodology developed by Garens (1997). DOIs are associated with these model datasets as of July 2016. These data are permanently stored at BSU. Lohse is in the process of getting a patent for Lohse, Patton, Godsey, Crosby associated with the thickness of mobile regolith process.

What is the impact on society beyond science and technology?

Public Outreach

We have worked to continue to engage the public in Critical Zone science and importance of soils as the foundation of terrestrial biomes and in providing many ecosystems and critical zone services. We participated in the Idaho State University STEM data outreach event (100+ students engaged directly), and the Pocatello Environmental Fair (100+ members of the public directly engaged). We developed a 3D model of a tree with a sap flux system on it to show people how we measured water flow in trees/shrubs and discussed basic ideas related to ecohydrology in water-limited environments. At RCEW, we implemented Owyhee Hydrology Camp in which 5 high school students from local schools plus 2 chaperones came out to Reynolds for two days to learn about soils and hydrology and the science conducted at Reynolds Creek. We also repeated our an 8th grade adventure learning expedition (4rd in row) at Reynolds Creek in which the McCall Outdoor Science School (MOSS) lead adventure learning in the RCEW for 23 students and 2 chaperones for 2 overnights at Reynolds Creek. Finally, Dr. Sarah Godsey and Ruth MacNeille initiated a program to broaden participation in STEM and spent a day with 20 Bannock Tribal youth and members in the field discussing job opportunities.

In year 4, we also focused a lot of our attention on engaging the public through informal education such as documentaries and a virtual watershed tour. *Voices of Fire is* a documentary that presents the different perspectives of the Soda Fire, a 200,000-acre fire that swept through the RC CZO, and presents different perspectives of management of the Reynolds Creek Watershed prior to and after the burn. It was produced and directed by a Montana State University science film student (RJ Sindelar) as his 2nd yr film project and partially supported by RC CZO. It competed in the Boise Film

Festival in September 2016 and won best student film. On August 10 and 30th 2017, *Voices of Fire*, premiered on Montana Public Television and then Idaho Public Television. We have also embedded this film into the criticalzone.org site (http://criticalzone.org/reynolds/education-outreach/) to make it publically available. As another element of our public outreach, we completed Reynolds Creek Virtual Watershed Tour (http://reynoldscreekczo.org/wordpress/). Videos were collected and interviews conducted during the summer of 2016 at RC CZO and resulted in the production of fourteen 2-4 minute videos as part of a Virtual Watershed Tour on subwatershed research topics. This project was as part of a SAVI/RC CZO funded outreach/education effort. Sindelar, who produced these videos for the virtual tour, is going to continue to revamp these videos as part of his final thesis in yr 5 and incorporate animations to explain concepts discussed in the videos.

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Changes/Problems

Changes in approach and reason for change

Soda Fire (week of August 10, 2015)
The Soda Fire occurred on the week of August 10th, 2015 and burned ~68 km^2 of 239 km^2 RCEW. The total area of the fire was >1100 km2—one of the largest fire in the United States. This resulted in loss of infrastructure including a climate station and weir housing at Salmon Creek.

- *Weirs* In response to this fire, the ARS restored the Murphy weir and are working to restore the Salmon weir though access is hampering progress.

- *Water sensors* We installed water sensors based on August 2015 Soda Fire in the following positions include Johnson Draw, Reynolds Creek (at Tollgate) and now at Murphy Creek, and the Outlet of Reynolds Creek. We also installed automated water samplers (Sigma samplers).

- *Dust collections* We installed about 12 dust collectors around the watershed consistent with the Southern Sierra CZO protocols for dust and microbial collections as part of Pierce rapid grant. The USGS (through collaborations) is distributing dust collectors (3-6) in closer proximity to fire to examine saltation following fire. These activities will allow us to quantify Aeolian inputs into the watershed from fire and other sources.

- Fire soil residues
- Dan Cadol and Amy Galanter (UNMT) This collaboration was sparked by conversations at an EPSCoR meeting and utilizes previously collected and archived soils from the JRB CZO (pre-fire) to evaluate the post-fire effects on carbon and fire residues and comparing one method to another fire residue method in collaboration with JRB CZO (Rasmussen). Cadol visited in June 2015 with an

EPSCoR tour of the RCEW and is interested in running samples after the prescribed fire (now Soda Fire).

- Dave Chandler and Chris Johnson (faculty at Syracuse University) and graduate student Yan Chen This collaborations was sparked by a visit in July to RCEW and collection of soil samples to be analyzed for fire effects of soil carbon following a 2007 prescribed fire. This thesis has been completed.

Other ongoing collaborations (External participants)

Treehugger (Evan DeLucia and Tim Mies)

This collaboration was sparked by Lohse contacting DeLucia to find out more information about their advertised Treehuggers –inexpensive, high resolution, automated dendrometer bands that can run $1500/band. DeLucia and Mies came out to Reynolds on May 18-21st and installed and trained RC CZO team on installation and troubleshooting of Treehuggers. ISU use participant support to support this travel.

WY CEGH and Steve Holbrook and team

This collaboration was sparked by Godsey attending the Drill the Ridge workshop and interactions with Holbrook from U of WY EPSCoR. Lohse spoke with Scott Miller and Holbrook at AGU 2013 and then in the spring established a date for a week long campaign (Aug 14-20th). Lohse used participant support to support per diem and travel to RC CZO. WY CEGH conducted surveys again in Yr 2 during the week of July 6-12th.

Sasha Reed, USGS

This collaboration was sparked by Lohse when her graduate student, Stacy King, expressed interest in determining nitrogen fixation and the microbial community associated with it. Lohse's lab does not have facilities to determine ethylene so that she contacted Sasha Reed, a known leader in this field on this topic, and a collaboration was commenced in May.

Julia Perdrial, Univ. of Vermont

Lohse engaged Perdrial (young investigator and previous CZO postdoc with JRB) to analyze RC CZO stream water samples for fluorescence index (FI) and Specific UV Absorbance (SUVA)

Katherine Renwick and Ben Poulter (University of Montana, now NASA Maryland)

RC CZO engaged with modelers to use EC to understand role of phenology on carbon balance

Rob Jackson and Sheringh Tumber-Davila

Lohse engaged with Dr Rob Jackson and his student Sheringh at Stanford University on using Reynolds Creek CZO as a platform to test hypotheses about rooting depth and bedrock thickness.

Actual or Anticipated problems or delays and actions or plans to resolve them

Permitting

Pierson and ARS continue discussions with the BLM and Shoshone-Paiute Tribe with regards to permitting the juniper selected site as a CORE site and getting permission to install the eddy covariance systems and other instruments as part of the CORE site at this location. This location has historical and cultural importance to the Shoshone-Paiute Tribe in this region.

Federal hiring freezes

The ARS has experienced intermittent hiring freezes for the past two years as a result of federal budget negotiations. This has made it difficult for us to employ the technician support we originally projected. It appears that these restrictions have eased and we anticipate filling the required positions.

Graduate students
Boise State University is responsible for the integrated modeling component, and a graduate student leading this effort departed for a more lucrative position. We have incurred delays but are in the process of hiring a postdoc to fill these deliverables in yr 4 and yr 5.

Changes that have a significant impact on expenditures

Loss of ARS personnel ARS lost CZO research technician (Wilford) in July 2016 and this position still hasn't been filled due to hiring freezes. This line is currently being advertised in the end of September.
Data manager ISU has leveraged EPSCoR funds to fund the database manager at ISU and needs to bridge these funds starting May 2018 (6 month salary).

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use or care of biohazards

Nothing to report.

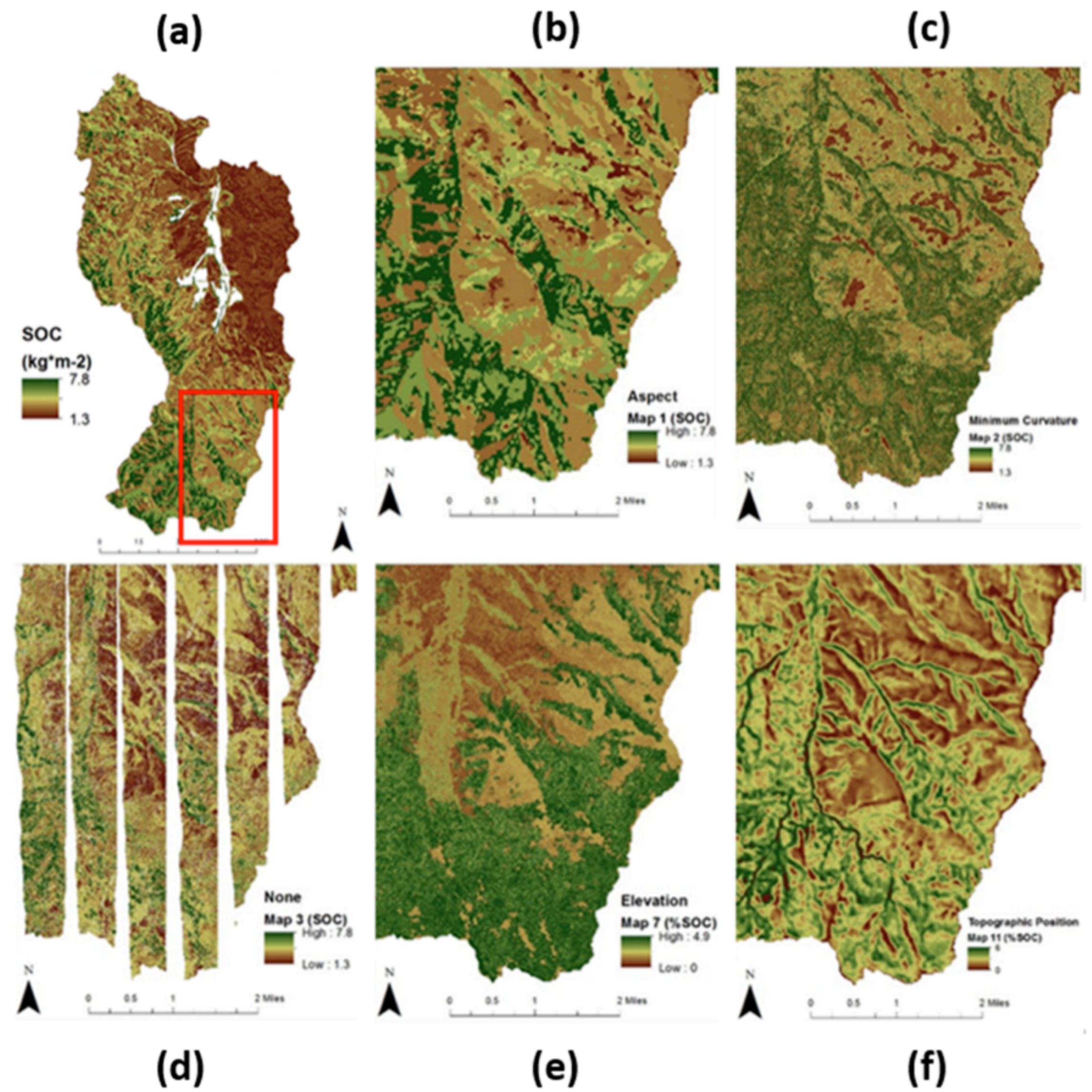


Figure 1.1a: Extent of close-ups shown in Figure 1.1a (b-f). b. Close up of Map 1 (SOC) where aspect was selected as a predictor. c. Close up of Map 2 (SOC) where minimum curvature was selected as a predictor. d. Close up of Map 3 (SOC) where no topographic variables were selected. e. Close up of Map 7 (%SOC) where elevation was selected as a predictor. f. Close up of Map 11 (%SOC) where topographic position index was selected as a predictor (Will 2017, Will et al. 2017 DOI)

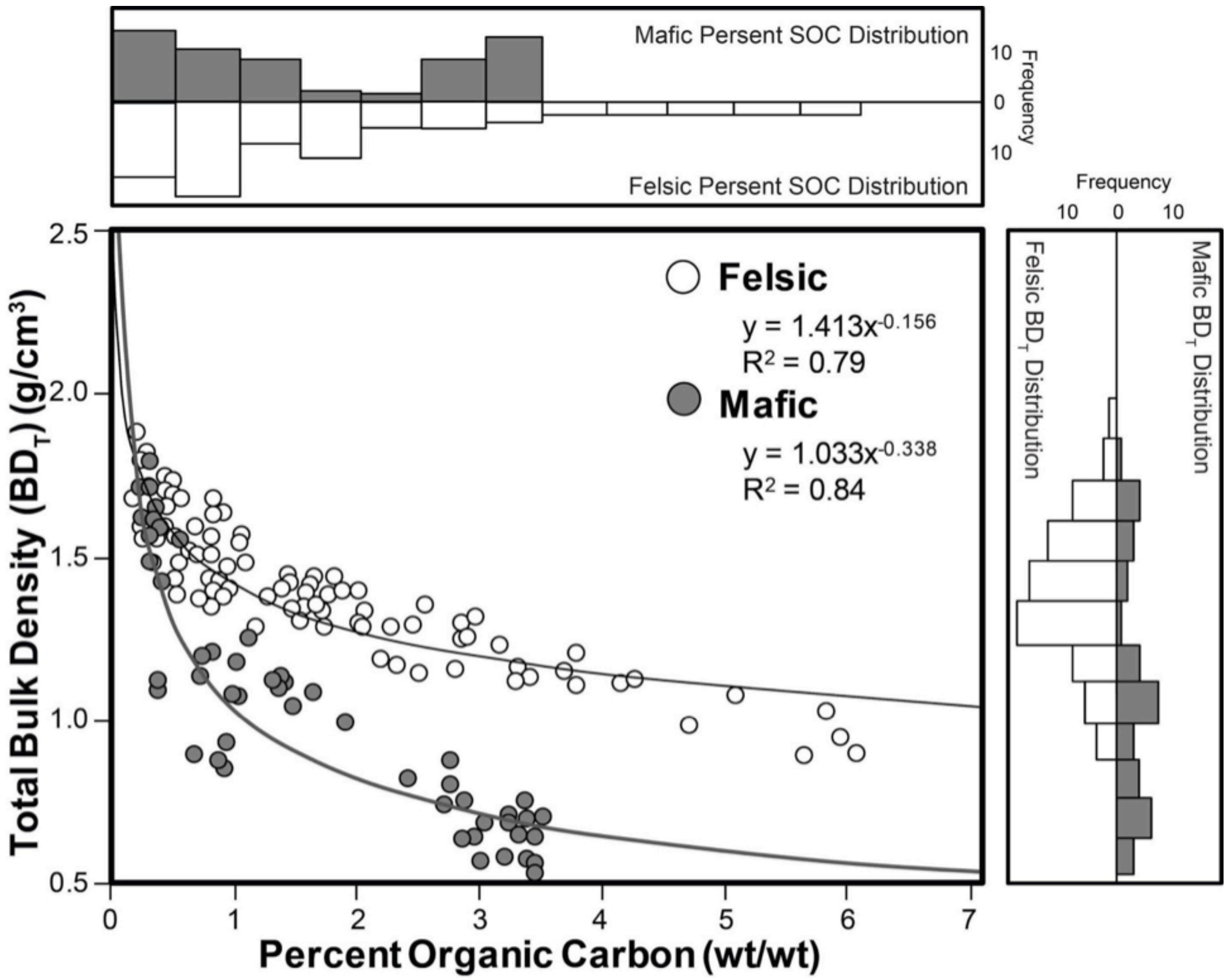


Figure 1.1b: Total bulk density using soil organic matter for felsic and mafic materials (mafic not shown) (Patton et al in review)

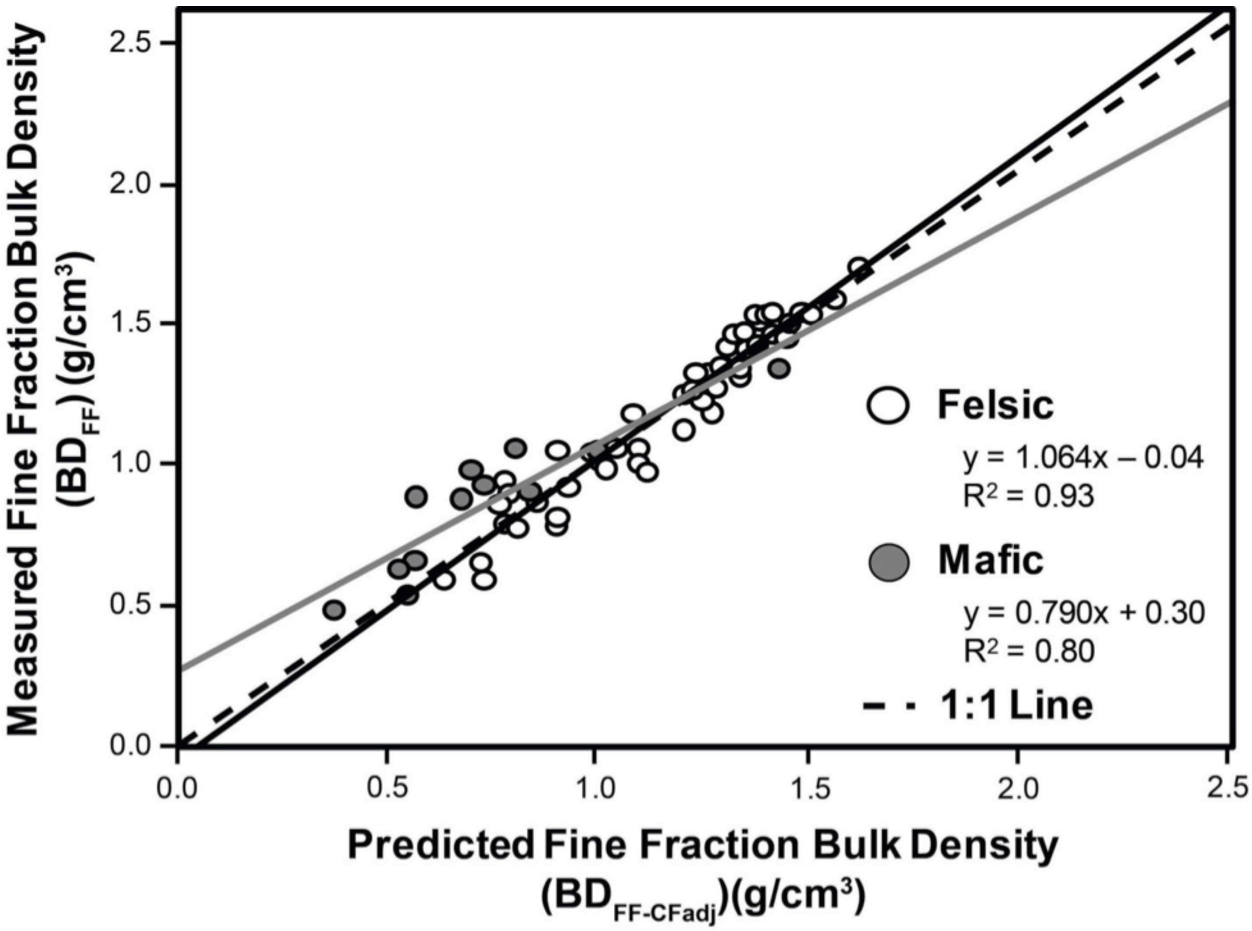


Figure 1.1c: Comparison of coarse fraction adjusted bulk density method using soil organic matter relationship to traditional fine-fraction core bulk density method (Patton et al. in review)

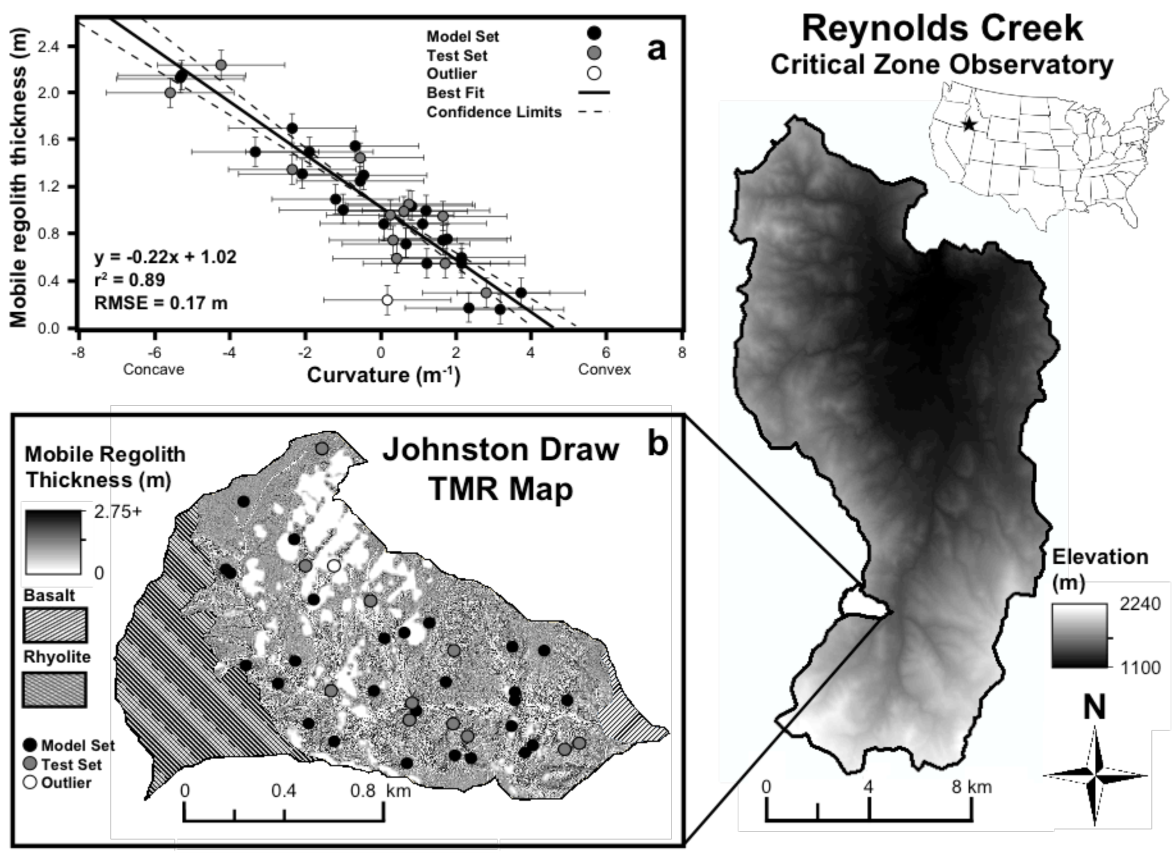


Figure 1.2a: (A) The thickness of the mobile regolith (TMR) varies as a strong inverse function of curvature in Johnston Draw. Black dots represent randomly selected build dataset (70% of sites). Gray dots represent test set to validate the model. The white dot is a location that was excluded owing to proximity to both a rock outcrop and a stream channel. (B) Predicted TMR map for Johnston Draw derived from the TMR-curvature function using a 3-m LiDAR-derived DEM. Darker shades indicate larger TMR (2.75+ m) and lighter shades indicate smaller TMR (0 m).

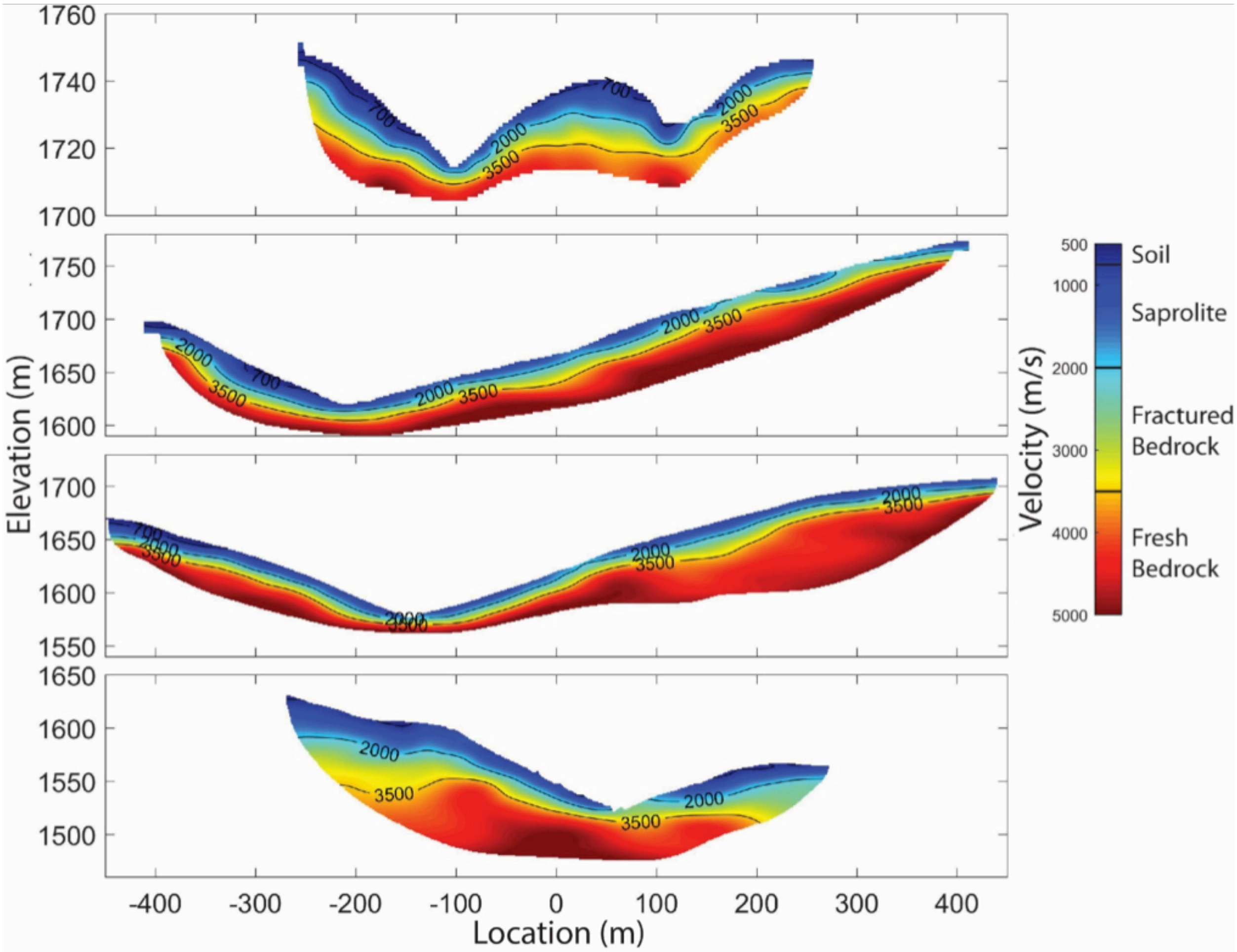


Figure 1.2b. Inverted velocity profiles for the seismic refraction surveys conducted in Johnston Draw with the 700m/s, 2000m/s, and 3500m/s velocity contours shown as black lines. The velocity contours correspond to the top of saprolite, fractured bedrock and unweathered bedrock, the velocity ranges for these layers is shown in Table 2. Line 1 (a) is vertically exaggerated by 3 times while all the other profiles have no vertical exaggeration.

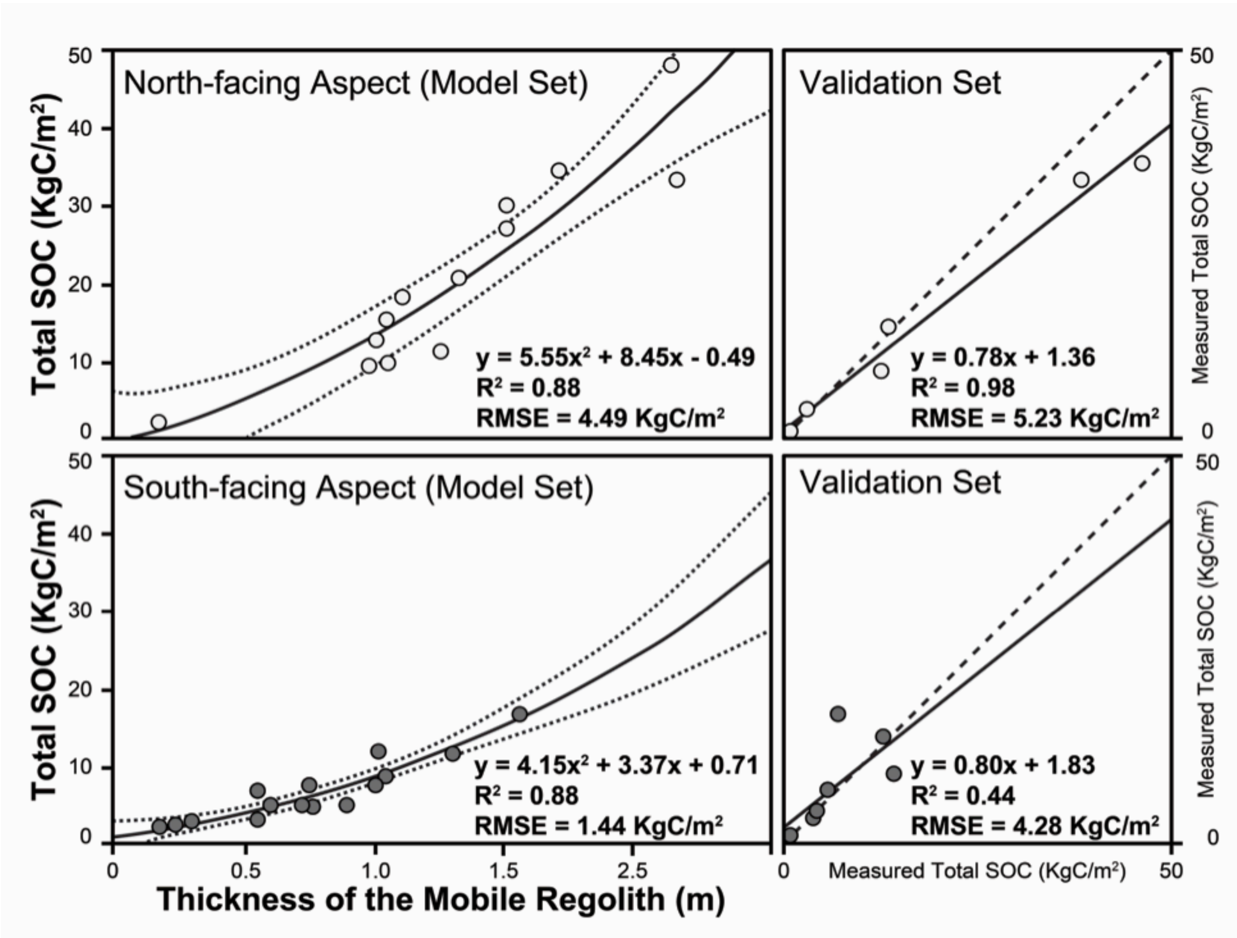


Figure 1.3a: Thickness of mobile regolith to total soil organic carbon (TMR-SOC) functions for north- (white dots) and south-facing (gray dots) aspects depicting a second order polynomial relationship (solid line) bound by 95% confidence intervals (dashed line). TMR-SOC functions were derived from a model set consisting of 70% of all sites. The remaining 30% of sites were utilized as a validation set and evaluated against a 1:1 line (dashed line) in predicted versus measured graph. For each polynomial there is an overall slight underestimation of total SOC. South-facing validation points shows a large variability in predictive ability; however, site jdt124b aspen was anomalously high and if excluded from this research the r^2 would be 0.79, RMSE of 2.49 KgC/m^2, p-value of 0.0181, and with no change in slope (Patton et al., in review)

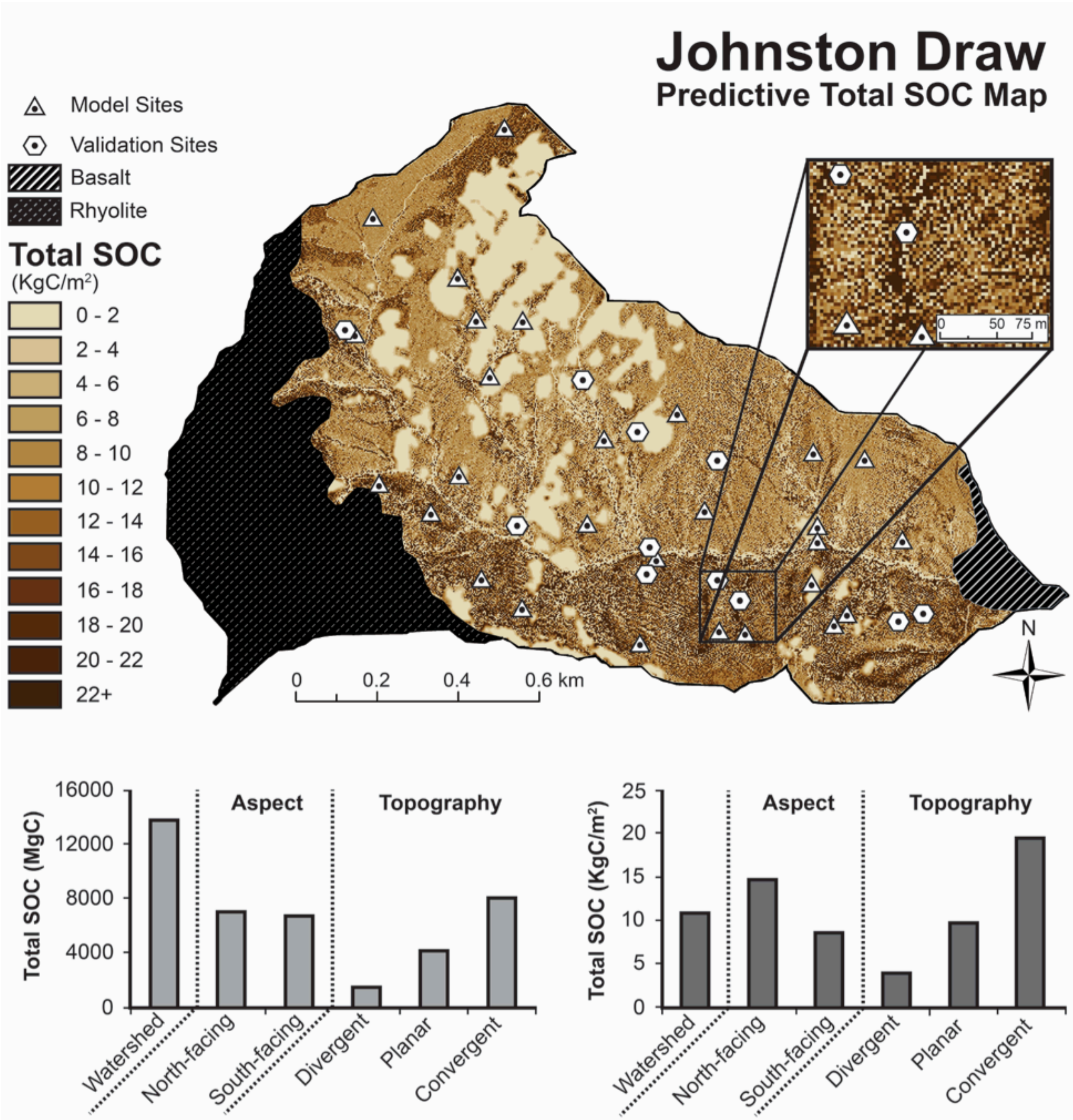
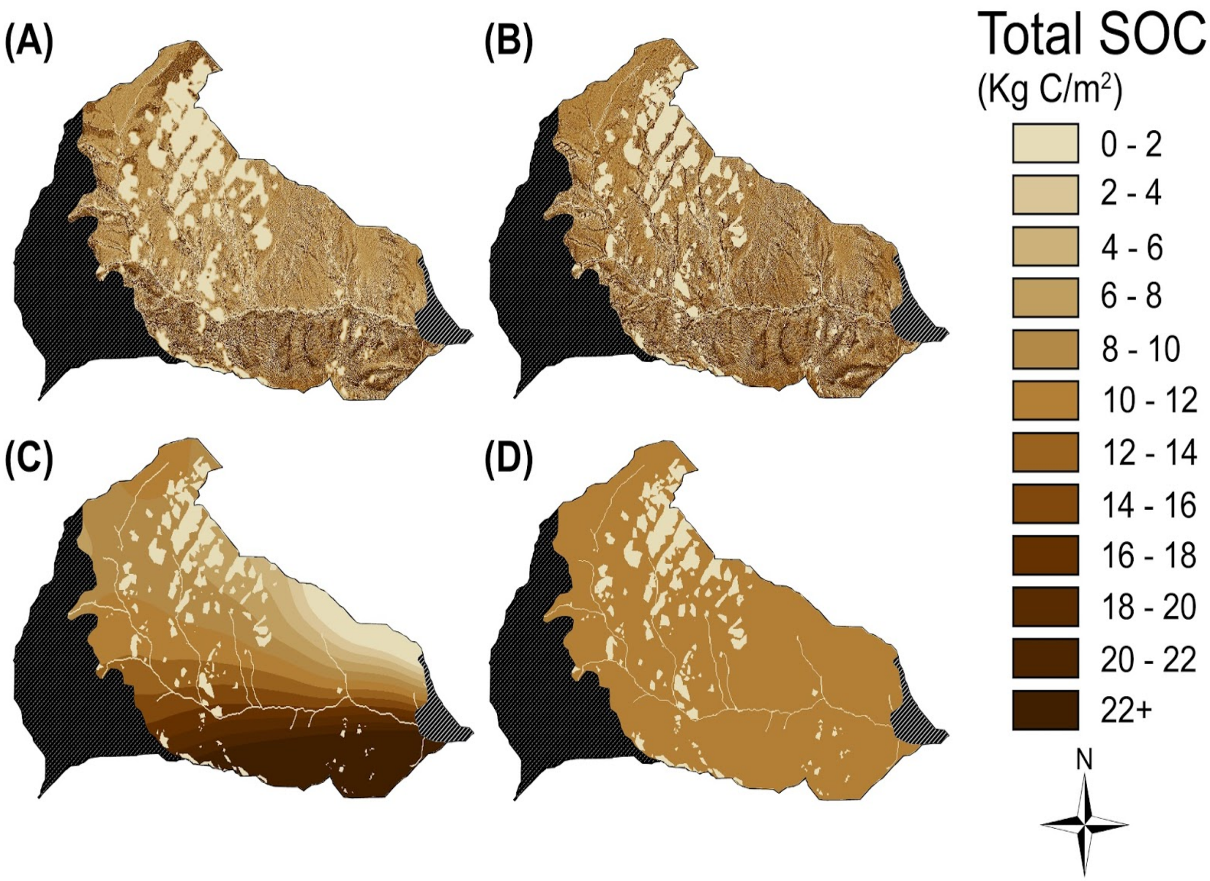


Figure 1.3b: Estimates of total SOC was extrapolated across the granitic portion of Johnston Draw watershed using a 3 m soil thickness DEM developed by Patton et al. (2017) and our TMR-SOC function developed from a model set (triangles) and tested against a validation set (pentagons). Predictive map shows visual evidence total SOC varying with aspect and with topography. Total SOC concentration are low on ridges and noses (light tans) and increase moving towards hollows and valleys (dark browns) (Patton et al. in review)



Method	Total SOC (MgC)	Percent Relative to Our Study						Model Validation			
		Total	North	South	Divergent	Planar	Convergent	R^2	RMSE (KgC/m^2)	MPE (KgC/m^2)	SDPE (KgC/m^2)
This Study (A)	13778	100	100	100	100	100	100	0.75	7.74	-4.91	5.98
Regression Kriging (B)	15163	110	89	132	94	114	113	0.82	4.77	-0.64	4.73
Kriging with Barriers (C)	17195	125	138	111	353	128	71	0.33	9.28	-2.82	8.84
Rapid SOC Budget (D)	13773	100	74	127	276	113	57	NA	11.03	2.40	10.77

Figure 1.3c: Four methods of extrapolating total SOC are presented within the granitic portion Johnston Draw watershed (A-D). For each method, total SOC were compared relative to our study by aspects, topography, and watershed stocks. In addition to total stocks, SOC was examined spatially to observe trends in low to high SOC (light tans to dark browns) across the watershed. Table provides estimated total SOC stocks, percent relative to our study, and validation of all models relative to the sampling depth. For all methods we observe similar total SOC stocks; however, depending on the method (C and D), spatial distribution may be lost resulting in under- and over-estimations by as much as 57% to 353%. Method D, provides evidence that utilizing the average north and south-facing aspect cites located on planar surfaces

and weighing their values based on the percentage of land cover (32% and 62%, respectively), than a realistic general total soil carbon estimate can be obtained (Patton et al. in review).

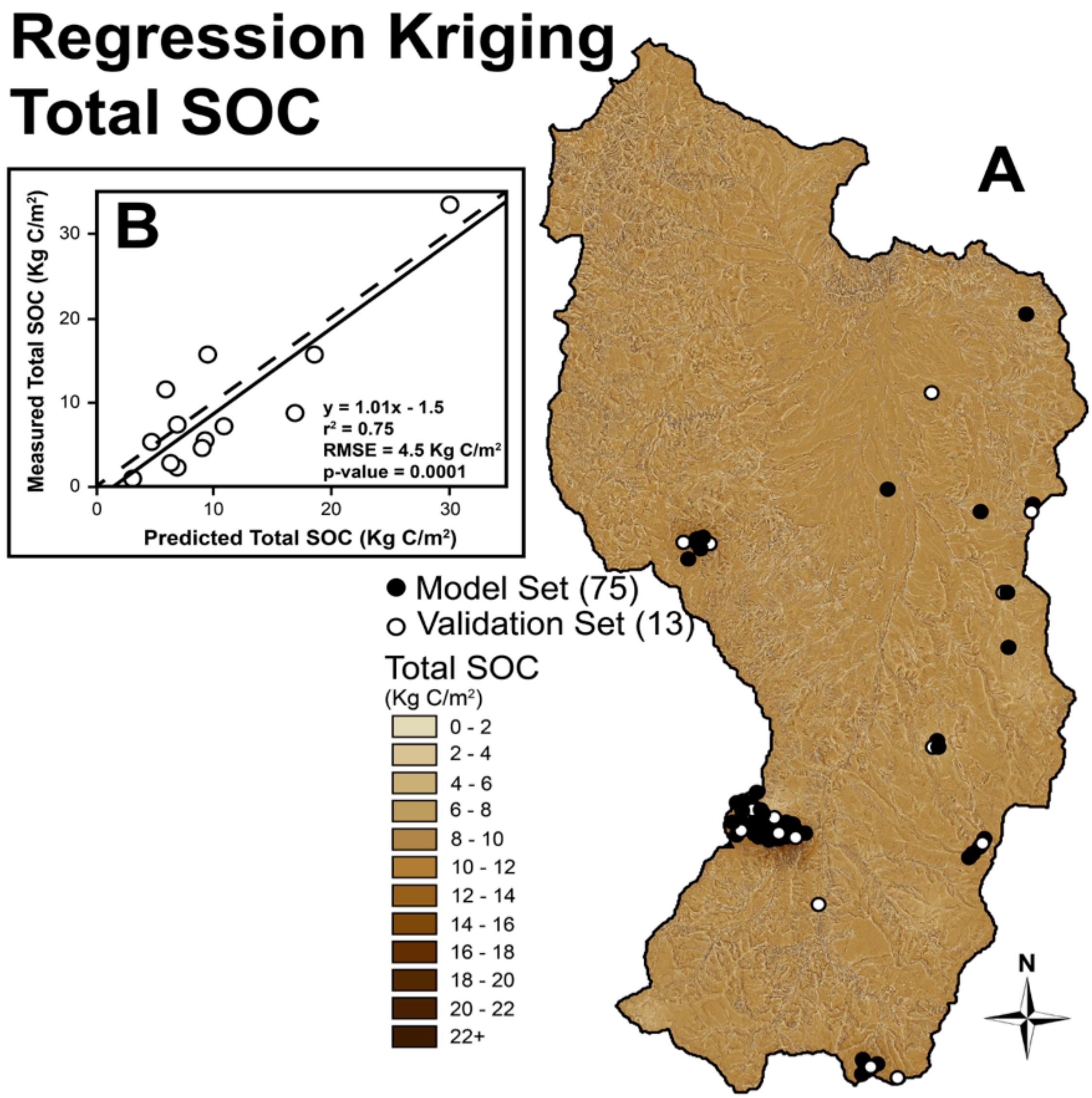


Figure 1.3d: Regression kriging techniques applied to predict total profile carbon across entire watershed using curvature as a covariate with the entire depth to saprolite determined (r^2=0.75).

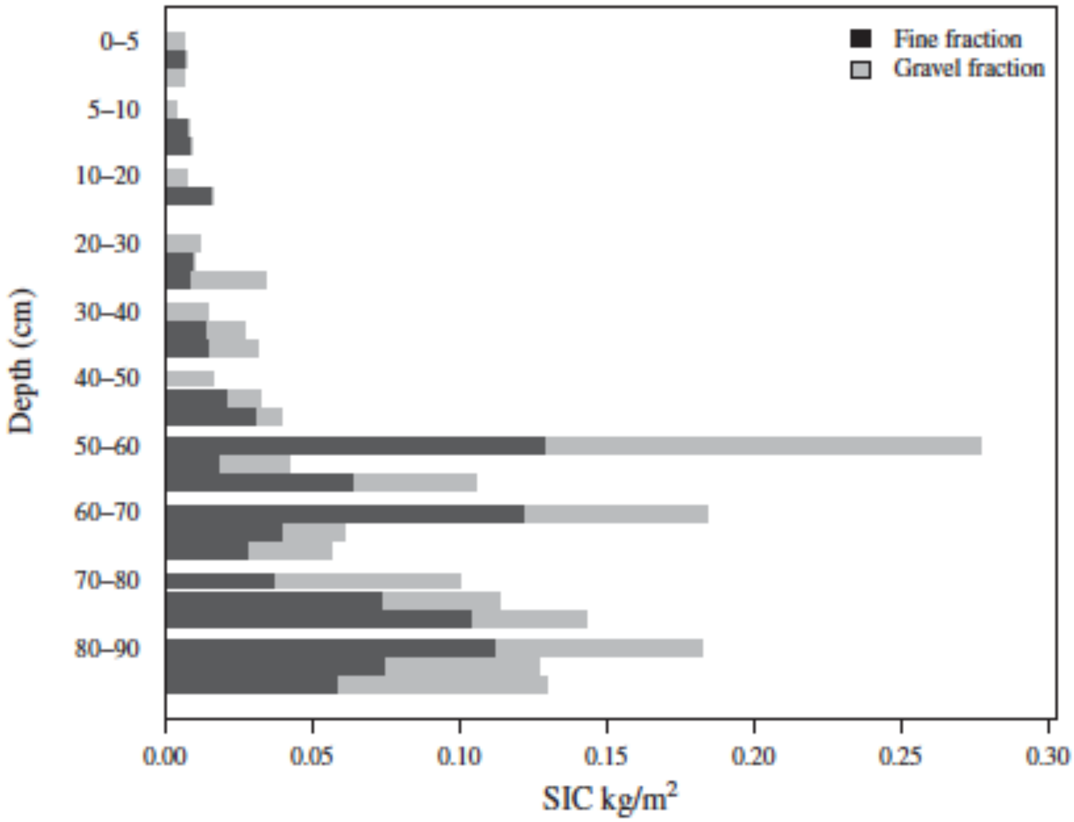


Figure 1.4a: Depth profile from site #13 showing a large portion of total SIC stored as car-bonate coatings on gravels. Approximately 44% of the total SIC at this site is stored as coatings. Each of the three bars at a depth show the values for a sampled profile within the soil pit (Stanbery et al. 2017)

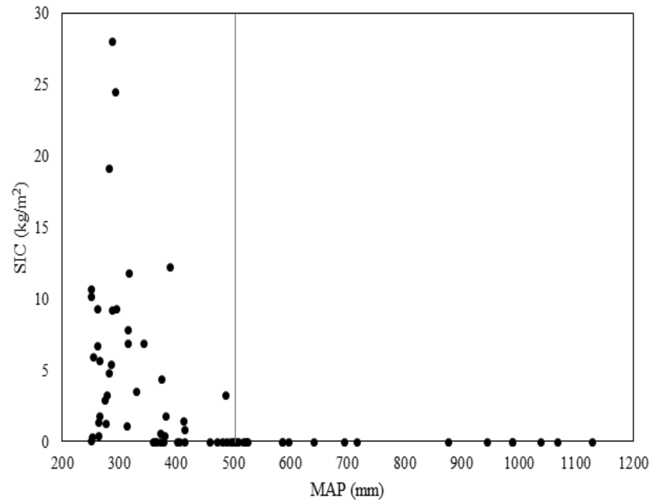
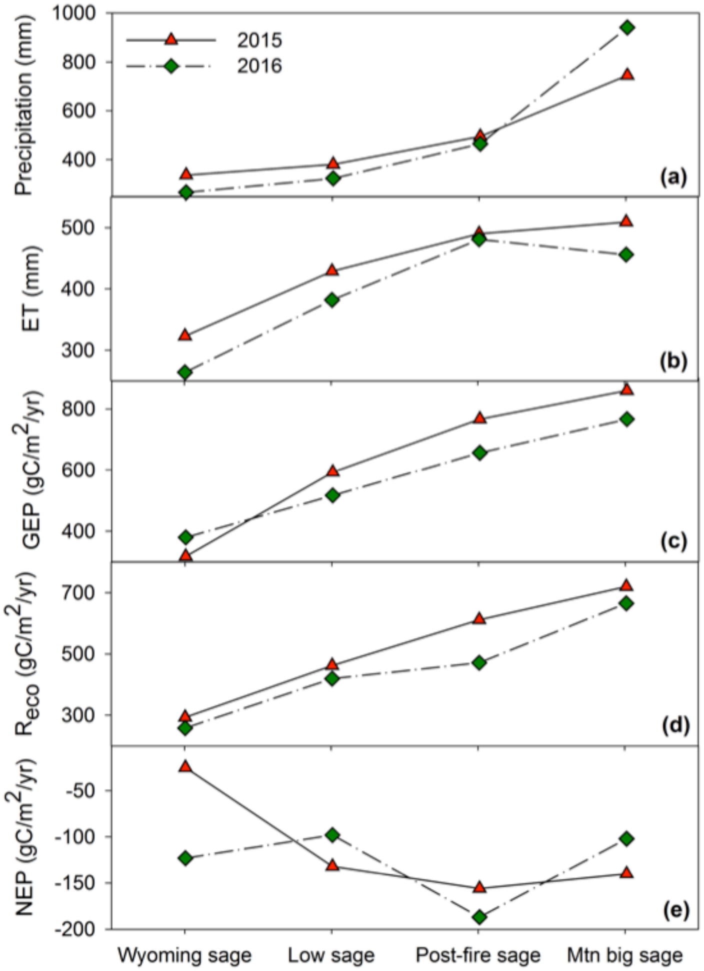
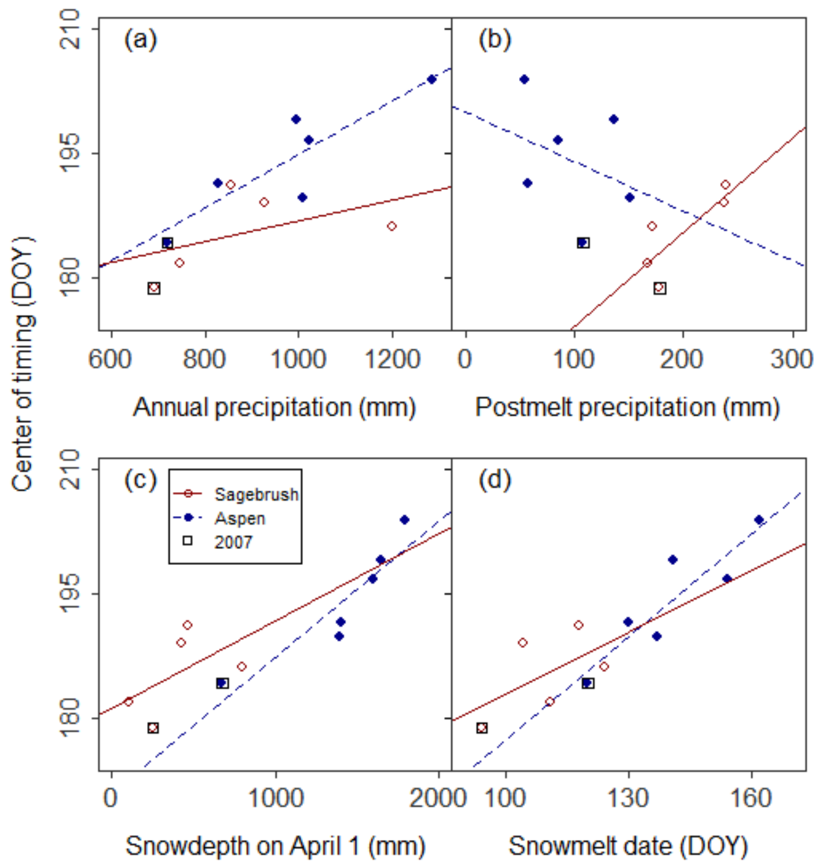


Figure 1.4b: Precipitation is a first order control on SIC presence/absence.

Figures: Priority 2



2.1a. Inter-annual variability in (a) precipitation, (b) evapotranspiration (ET), (c) gross ecosystem production (GEP), (d) ecosystem respiration (R_{eco}), and (e) net ecosystem production (NEP) across sites along RC CZO Climate Gradient Core Network. (Negative values of NEP indicate net flux of carbon to the ecosystem.) (Flerchinger et al. in review)



2.1b Variation in the center of timing of GEE (calendar Day Of Year; DOY) with (a) annual precipitation, (b) rain that fell after the perennial snowmelt melted (postmelt precipitation), and (c) the day that the perennial snowpack melted (Snowmelt date). Center of timing was calculated as Σ(GEE * DOY)/ ΣGEE (Fellows et al. in review).

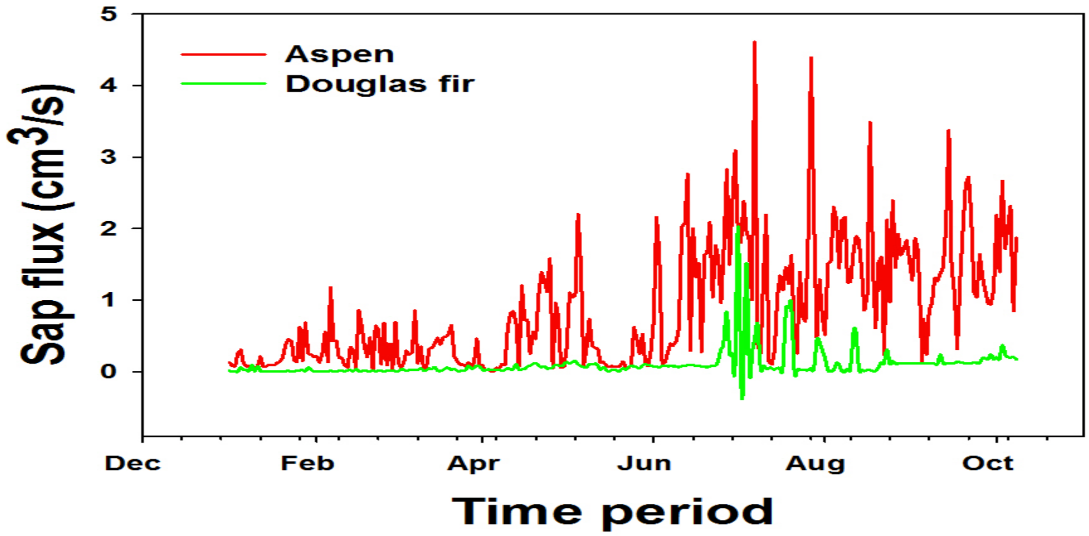


Figure 2.2. Daily sap fluxes in Aspen and Douglas Fir for 2016.

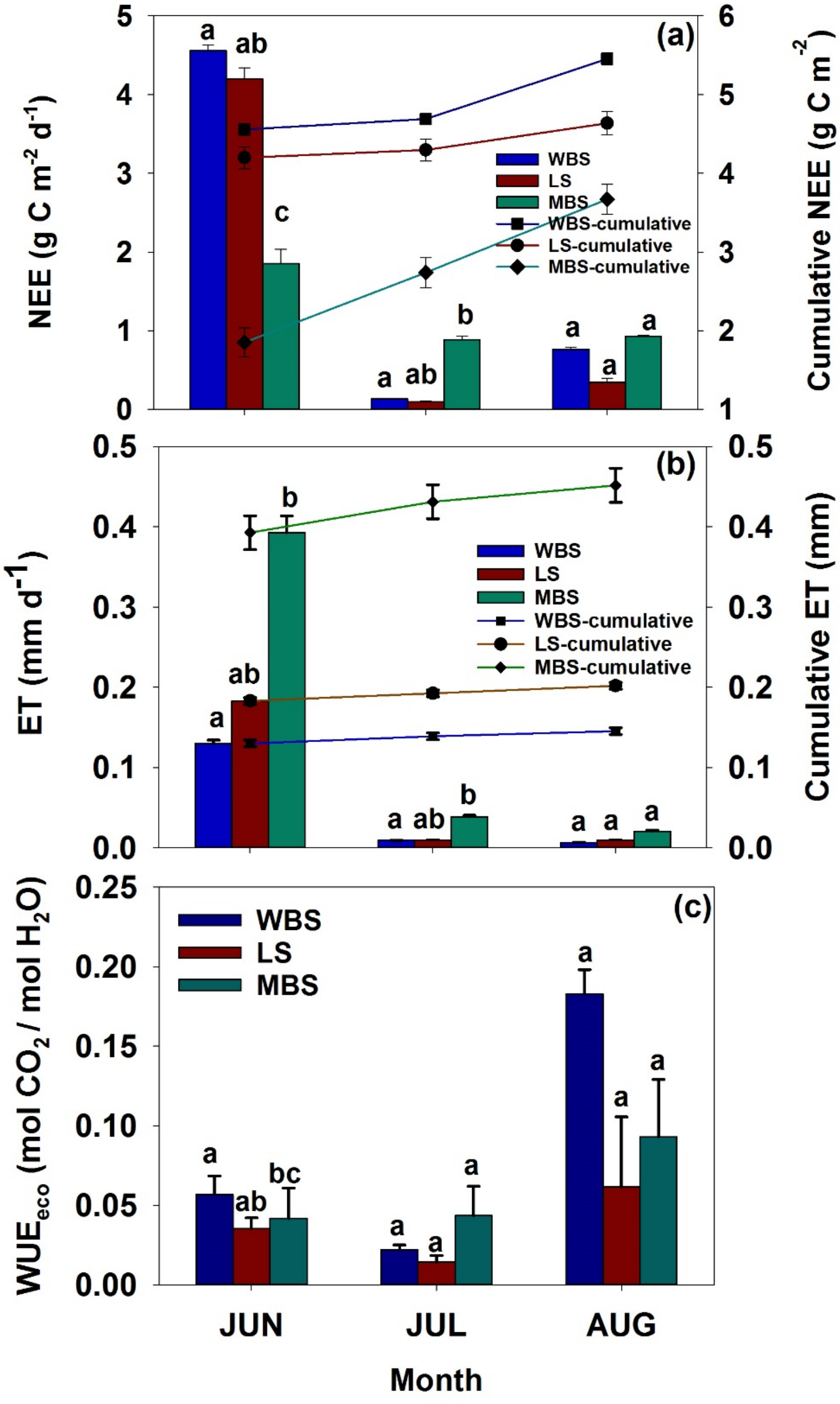


Figure 2.3. Daily (6:00 a.m.-6:00 p.m.) and cumulative (additive across months) net ecosystem exchange (NEE) (a), evapotranspiration (ET) (b), and water use efficiency (WUE_{eco}) (c) at Wyoming Big Sage (WBS), Low Sage (LS), and Mountain Big Sage (MBS) sites June-August, 2016. Bars are means $\pm$ SE. Different letters above the bars indicate significant differences among sites ($p<0.05$) within each month (Sharma et al. in review).

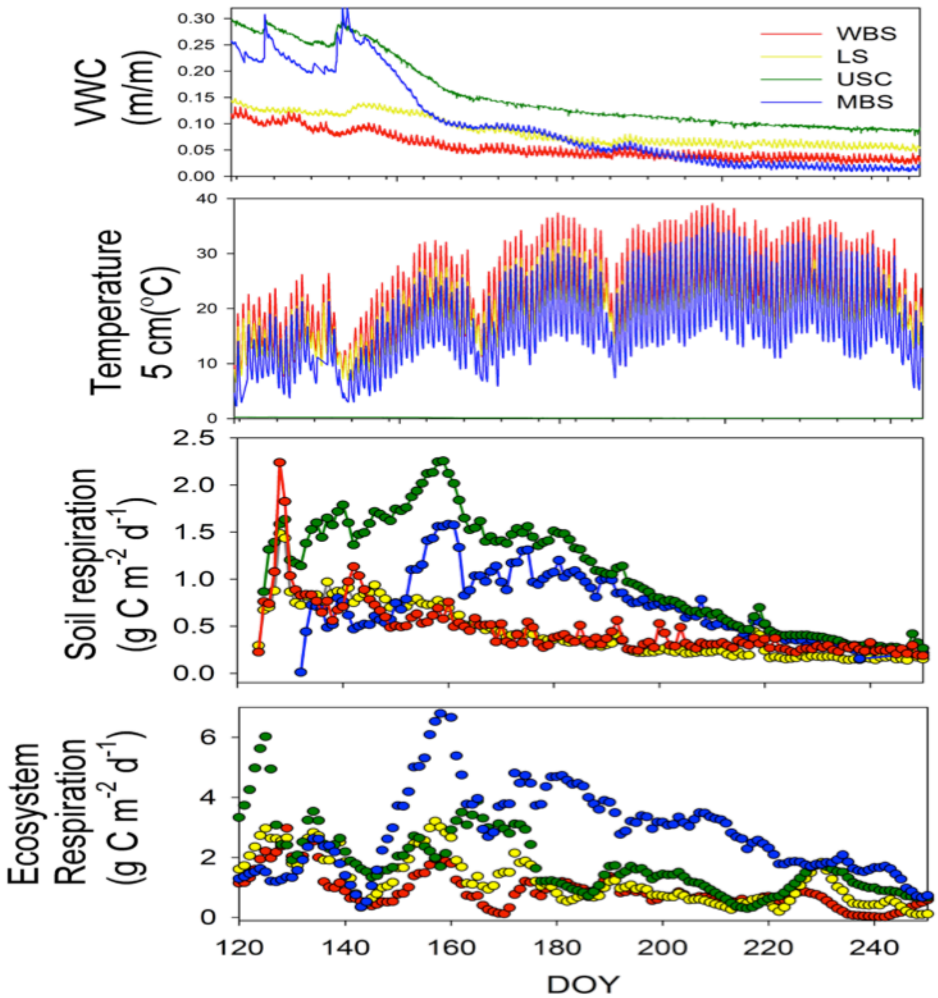


Figure 2.4. Daily CO_2 efflux measured from automated (every 15 minutes) forced diffusion chambers at core sites showing generally highest fluxes from Upper Sheep (US) compared to other sites likely owing to optimal moisture and temperature conditions.

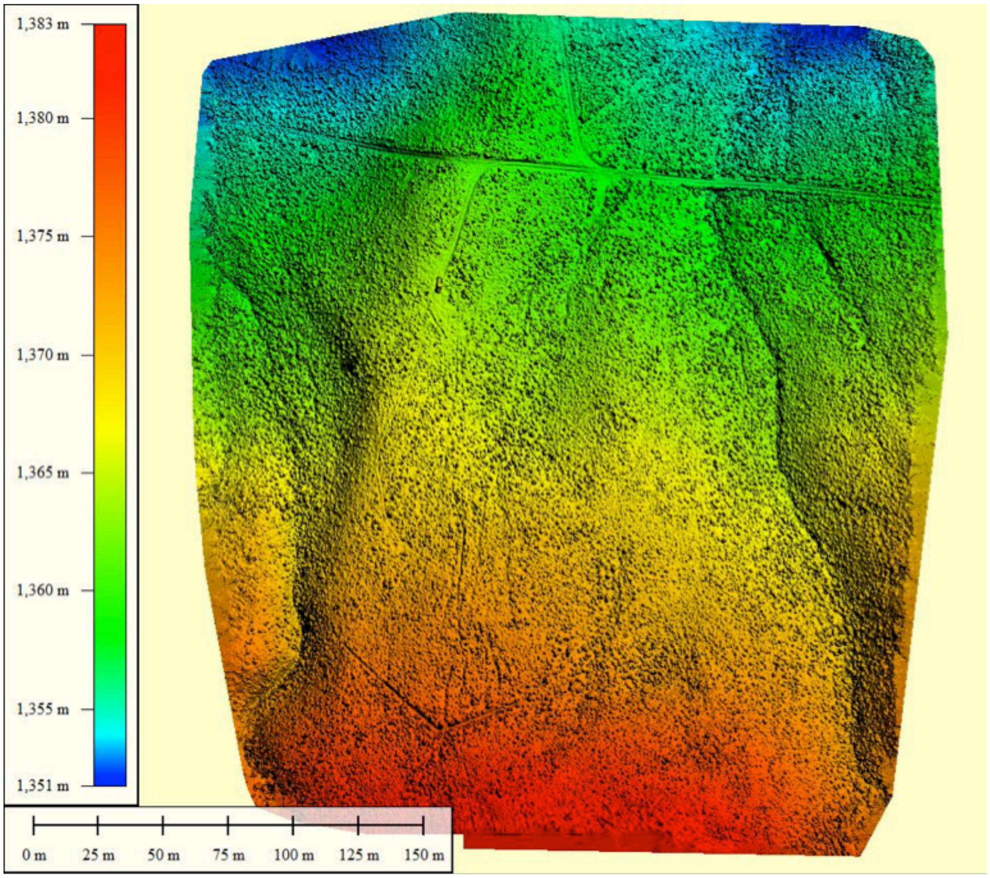


Figure 2.5: Very fine-scale digital surface model (DSM) (2-cm GSD) developed for each site using the UAV imagery and Pix4D software (for WBS CORE site)

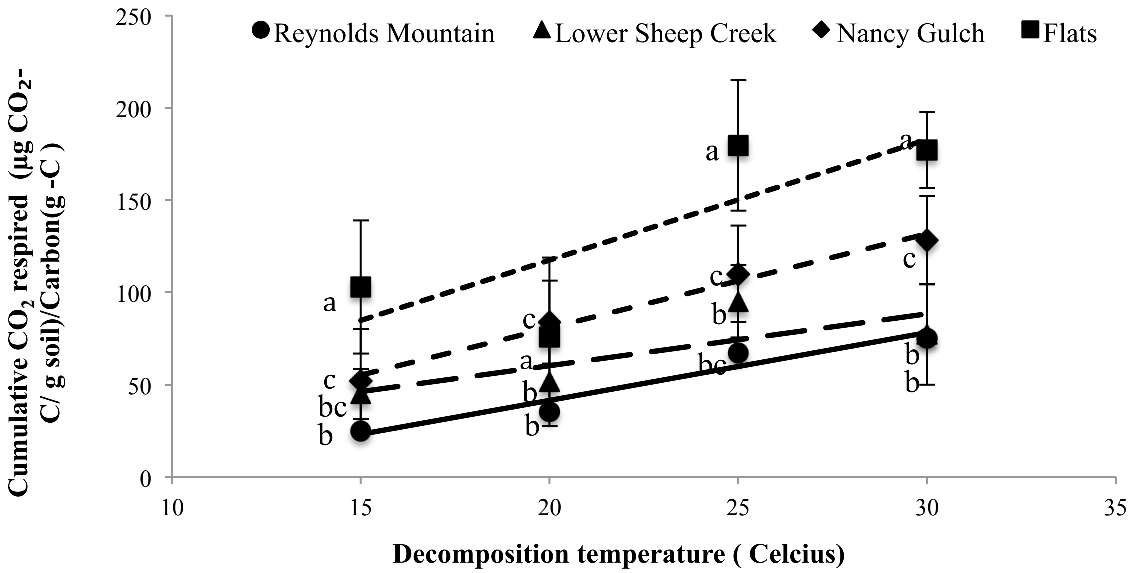


Figure 2.6. Cumulative CO_2_respired normalized with initial C by day 365 across temperatures and elevations. Values are means ± standard errors (n=5) and letters indicate differences among elevations (P<0.05).

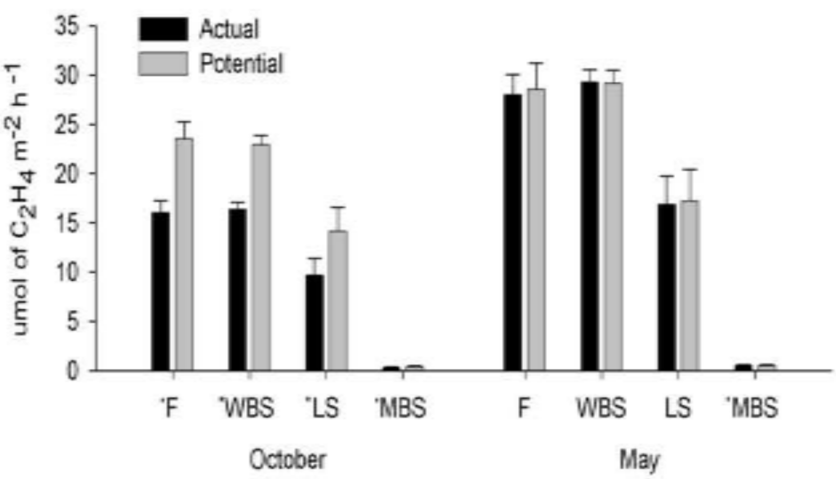


Figure 2.7a. Nitrogenase activity for samples measured at field moisture (actual) and those where water was added (potential) from October 2014 and May 2015. Values are means ± SE. An * shown near the site name on the x-axis denotes significant differences between actual and potential activity based on Wilcoxon Sign ranked test. Sites increasing in elevation are Flats (F), Wyoming Big Sage (WBS), Low Sage (LS), and Mountain Big Sage (MBS) (Schwabedissen et al., 2017)

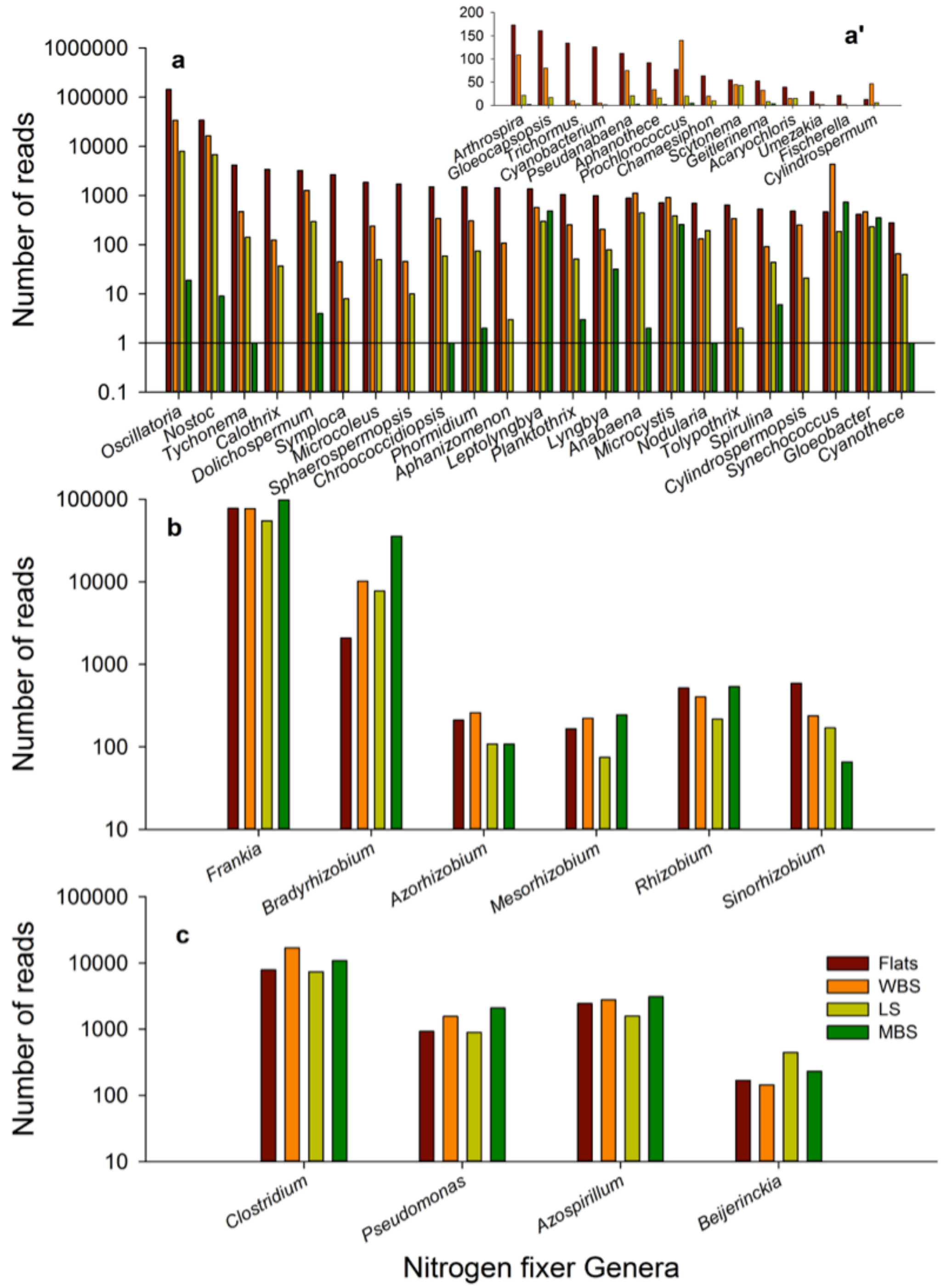


Figure 2.7b. Figure 3: Comparison of a) cyanobacteria and inset a' of minor cyanobacteria (<400 reads), b) symbiotic and c) other N fixing bacteria genera (mean number of three replicate reads on log scale) associated with different sites, Flats (F), Wyoming Big Sage (WBS), and Low Sage (LS) and Mountain Big Sage (MBS).

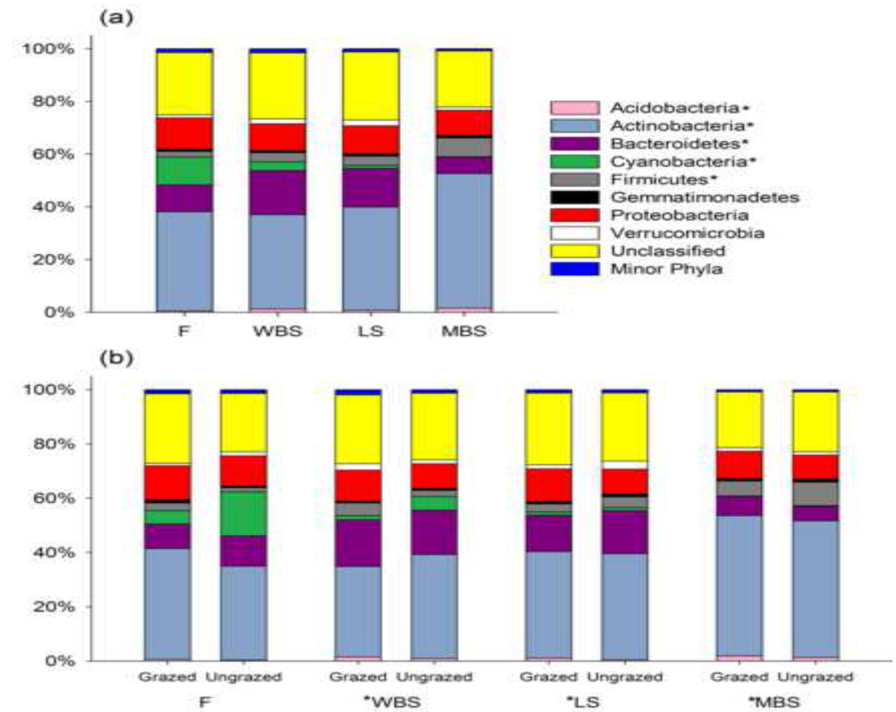


Figure 2.7c. (a) Average percent abundance of phyla at each elevation. * denotes significant differences ($P < 0.05$) with elevation. Minor phyla of Aquificae, Chloroflexi, Deinococcus-Thermus were also significantly different with elevation. (b) Average percent abundance of phyla by grazing disturbance at each elevation. * denotes significant differences ($P < 0.05$) in bacterial community between grazing and ungrazed: WBS Nitrospirae and Tenericutes; LS Acidobacteria; and MBS Lentisphaerae and Thermotogae. Site names increasing in elevation are Flats (F), Wyoming Big Sage (WBS), Low Sage (LS), and Mountain Big Sage (MBS)

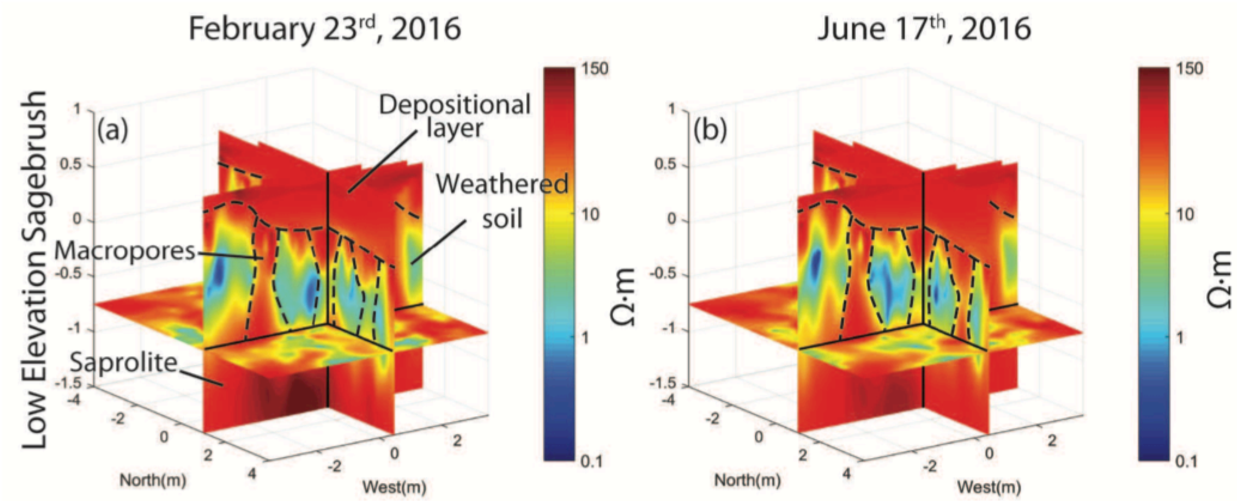


Figure 2.8: The resistivity grids from the static inversion of the February, 23rd, 2016 (a) and June, 17th, 2016 (b) surveys for the LES site. The colorbar ramps at a log scale but the values indicated on the colorbar are the true resistivity values. The dark dotted lines are the contact between the various soil structures and in (a) soil structures are labeled with our interpretation. While the soil moisture states are very different between the two surveys the resistivity structure remains largely the same.

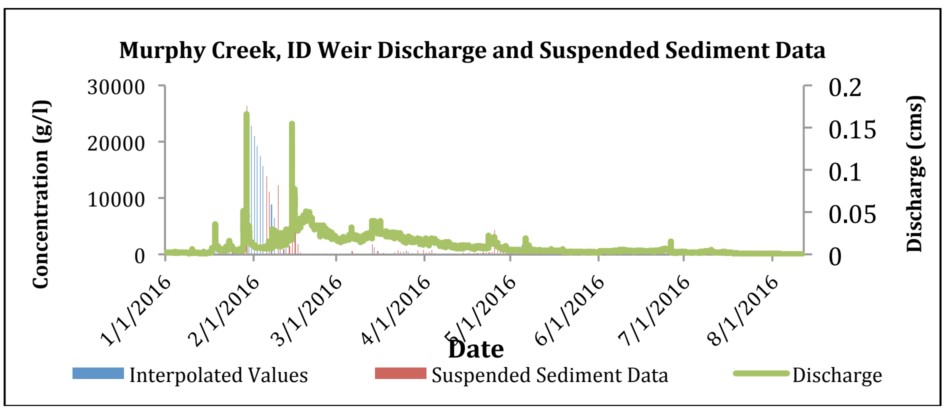
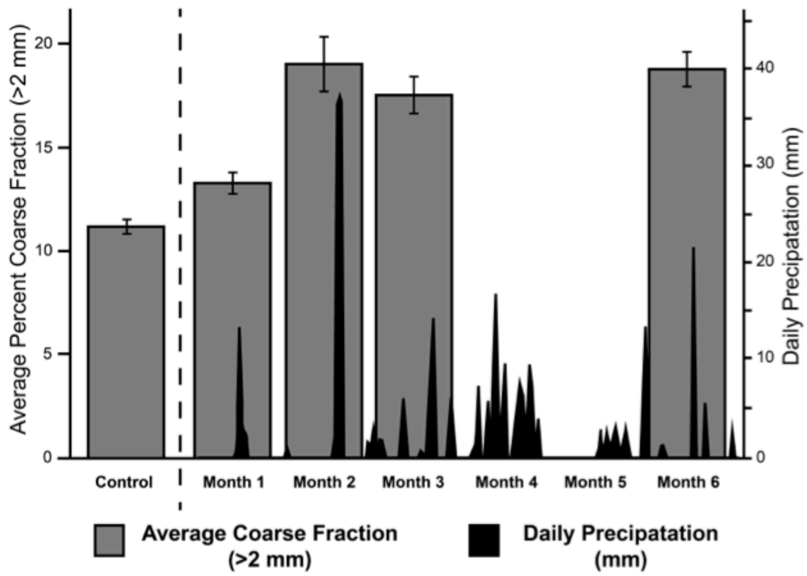


Figure 2.9a: Post-fire sediment delivery in Murphy Creek.



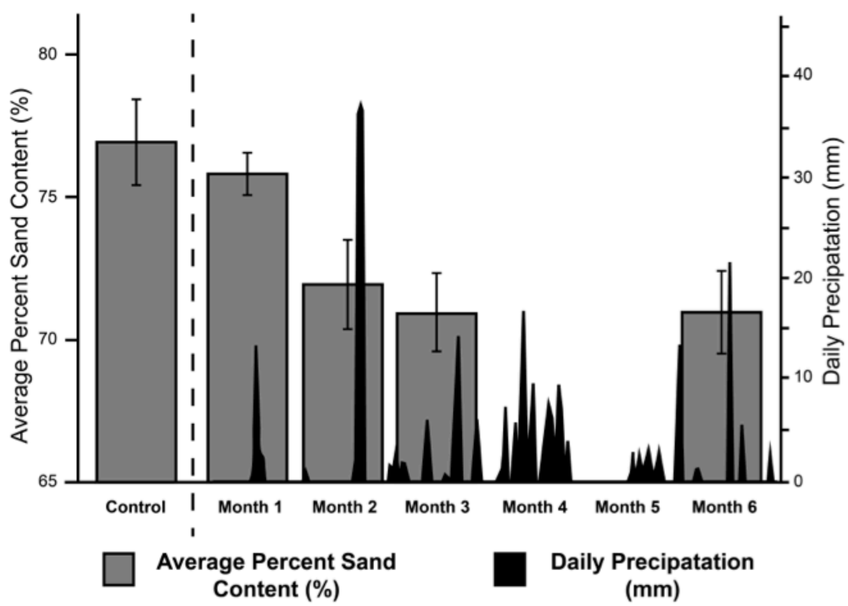


Figure 2.9b: Post-fire soil responses on north and south facing granitic hillslopes show no significant differences in soil C, N and C/N ratios 2 months post-fire.

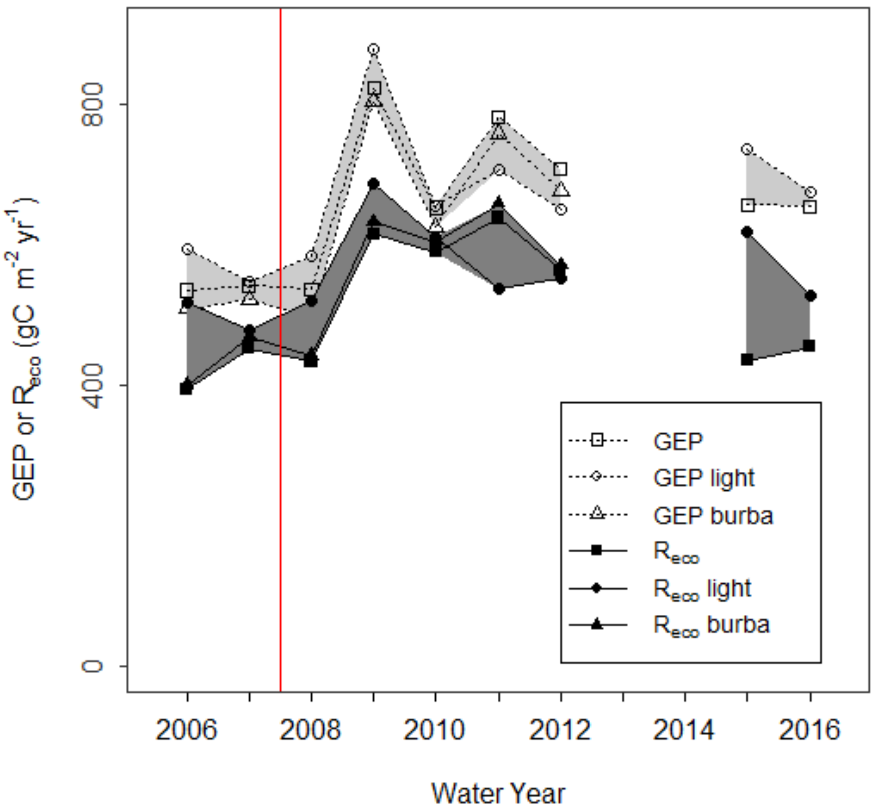


Figure. 2.9c. Pre- and post-burn Gross Ecosystem Production (GEP; gC m^{-2} yr^{-1}) and Respiration (R_{eco}; gC m^{-2} yr^{-1}). The site was burned in September 2007 (vertical red line). Annual GEP and Reco were estimated in three ways: (1) missing observations were filled with REddyProc (GEP and Reco; Reichstein et. al., 2005), (2) missing observations were filled with a light response curve (GEP light and Reco light), and (3) GEP and Reco were filled with REddyProc after adjusting the measured fluxes for sensor heating using Burba et al., (2008; GEP burba and Reco burba). Data show rapid recovery of GEP following fire.

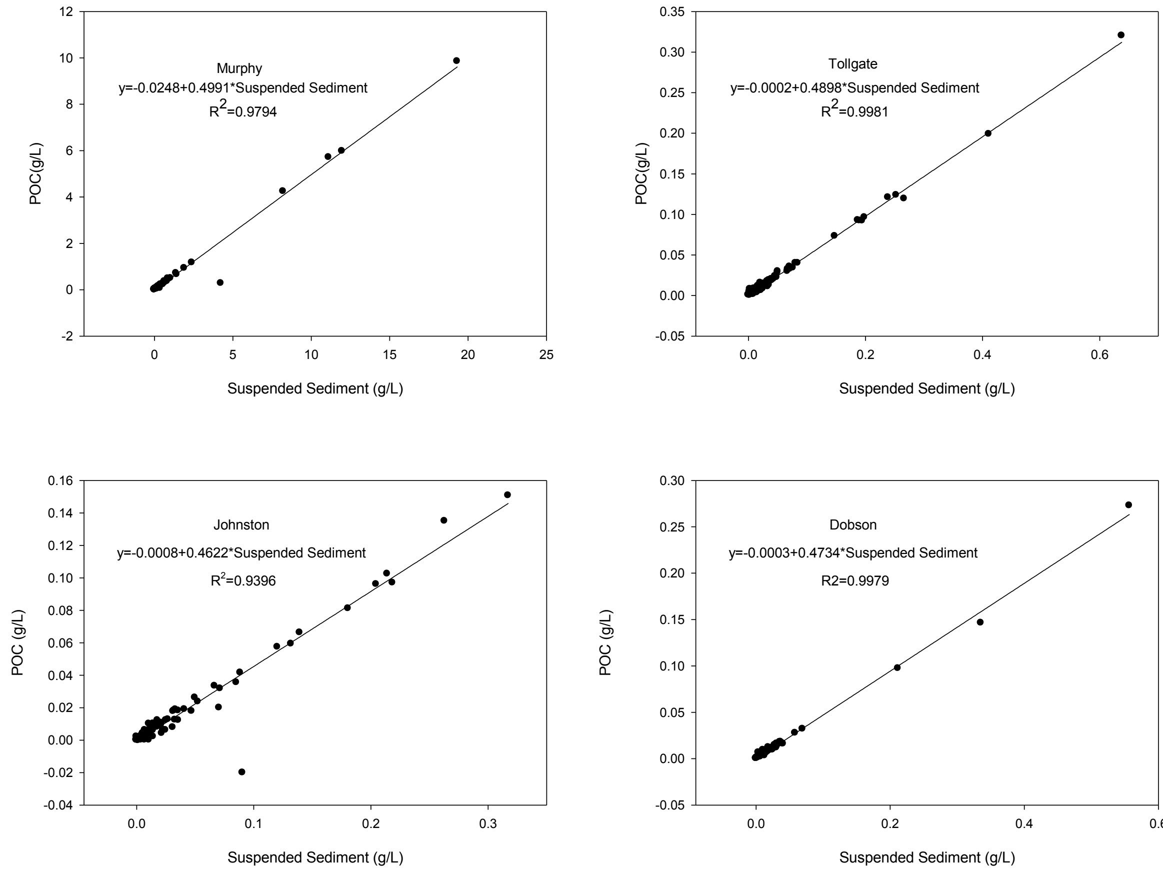


Figure 2.10a. Correlation of suspended sediment and particulate organic carbon (POC) in Murphy (burned), main stem (Tollgate), and tributaries (Dobson, Johnston). Note suspended sediment is 5-20 time higher in Murphy than other reaches.

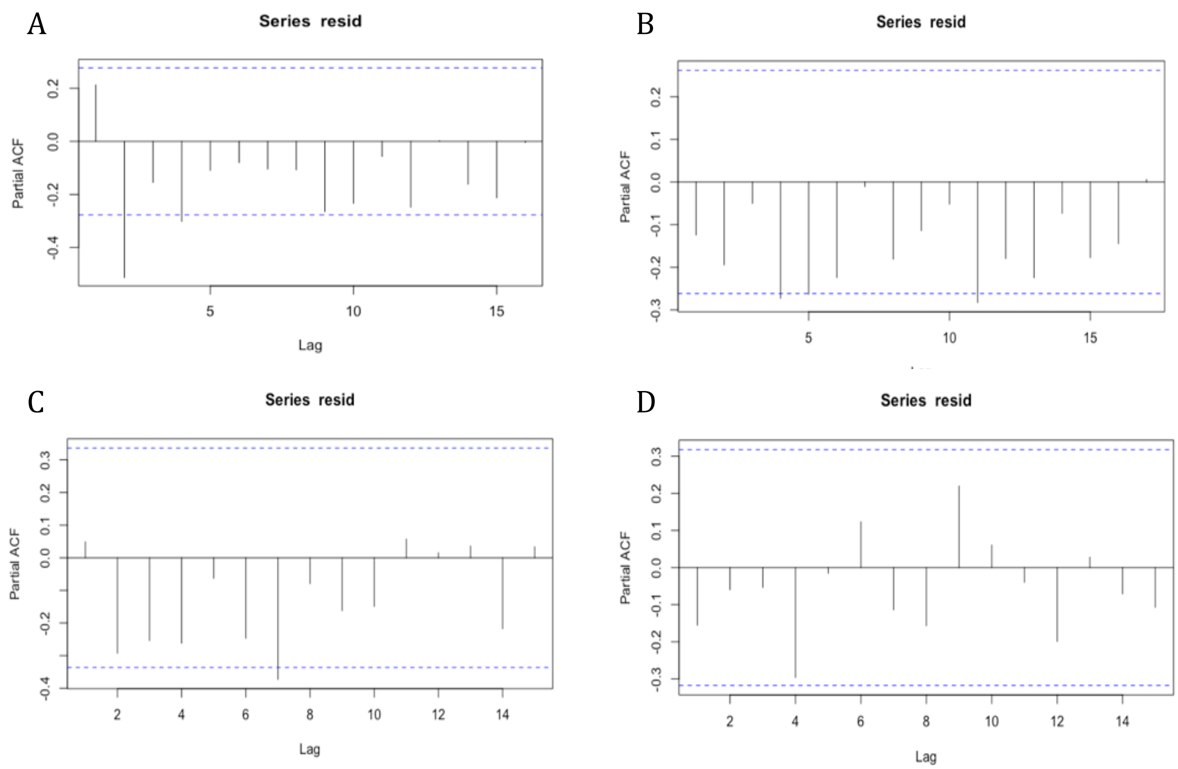


Figure 2.10b. Analysis of heterogeneity across temporal scales was conducted using partial autocorrelation function plots (pacf plots). These plots examine autocorrelation patterns between residuals of the best fit model. A information criteria corrected (AICc) were used to determine best model fit. The plots illustrate an increasing heterogeneity in DIC concentrations from April to June where April is autocorrelated and June is not. Pacf plots for the unburned stream in April (A) and June (C) and the burned stream in April (B) and June (D).

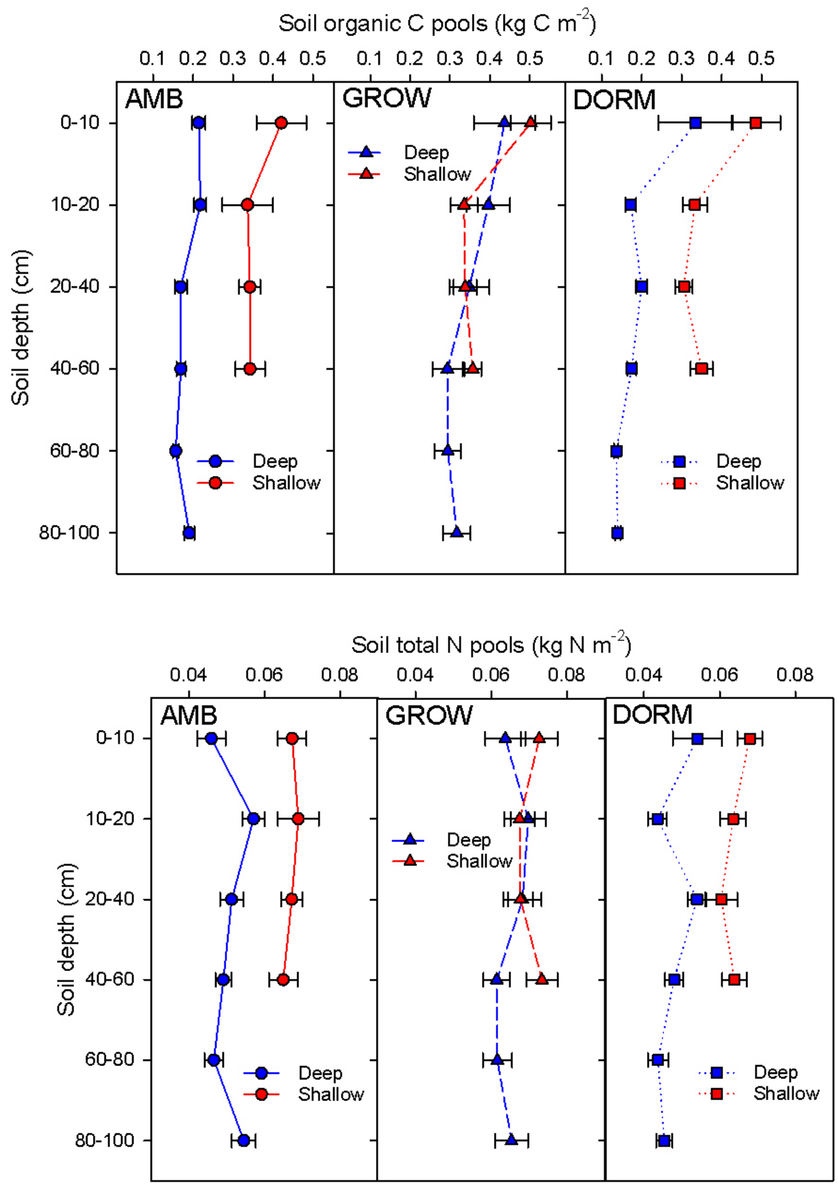
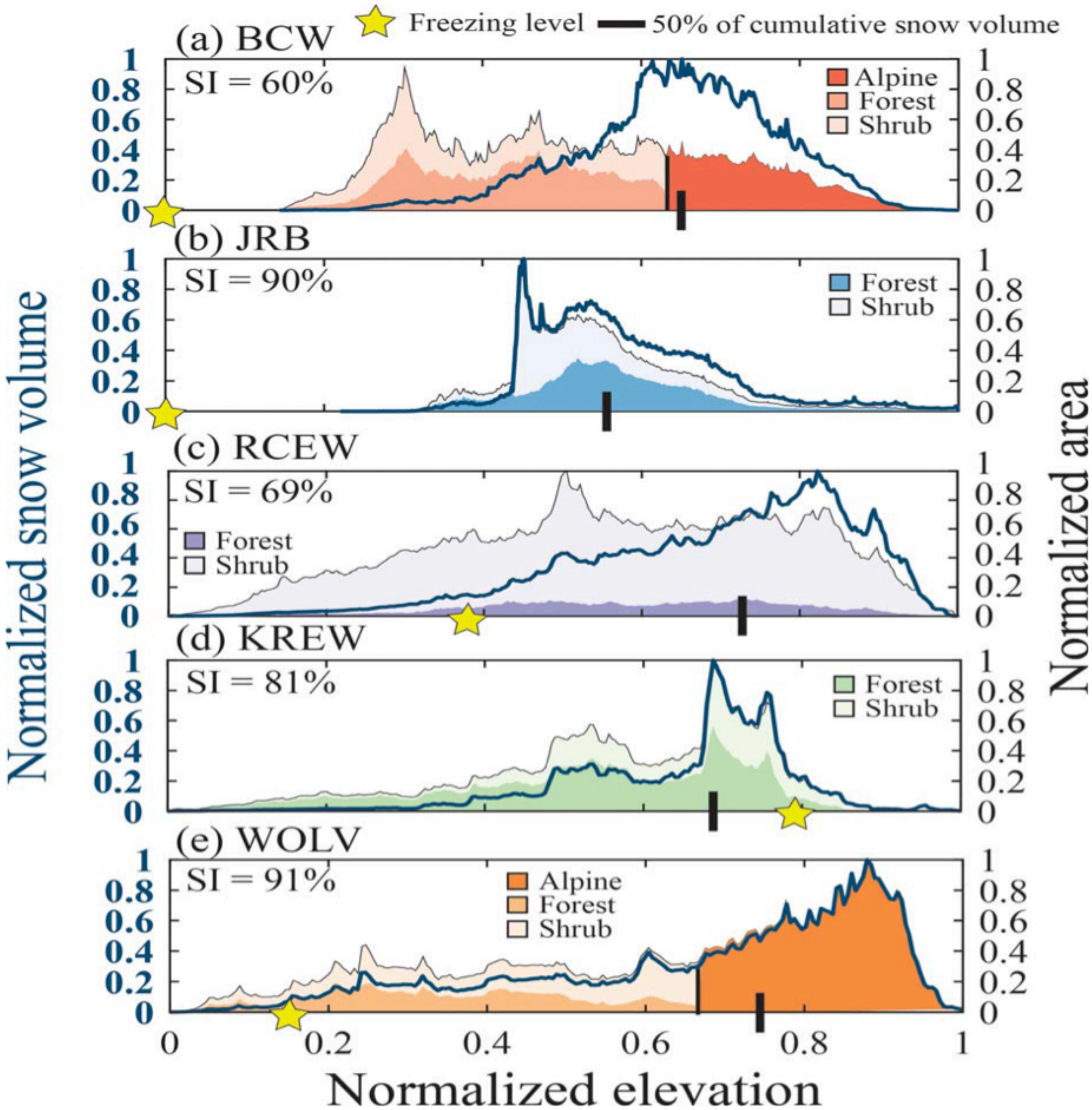
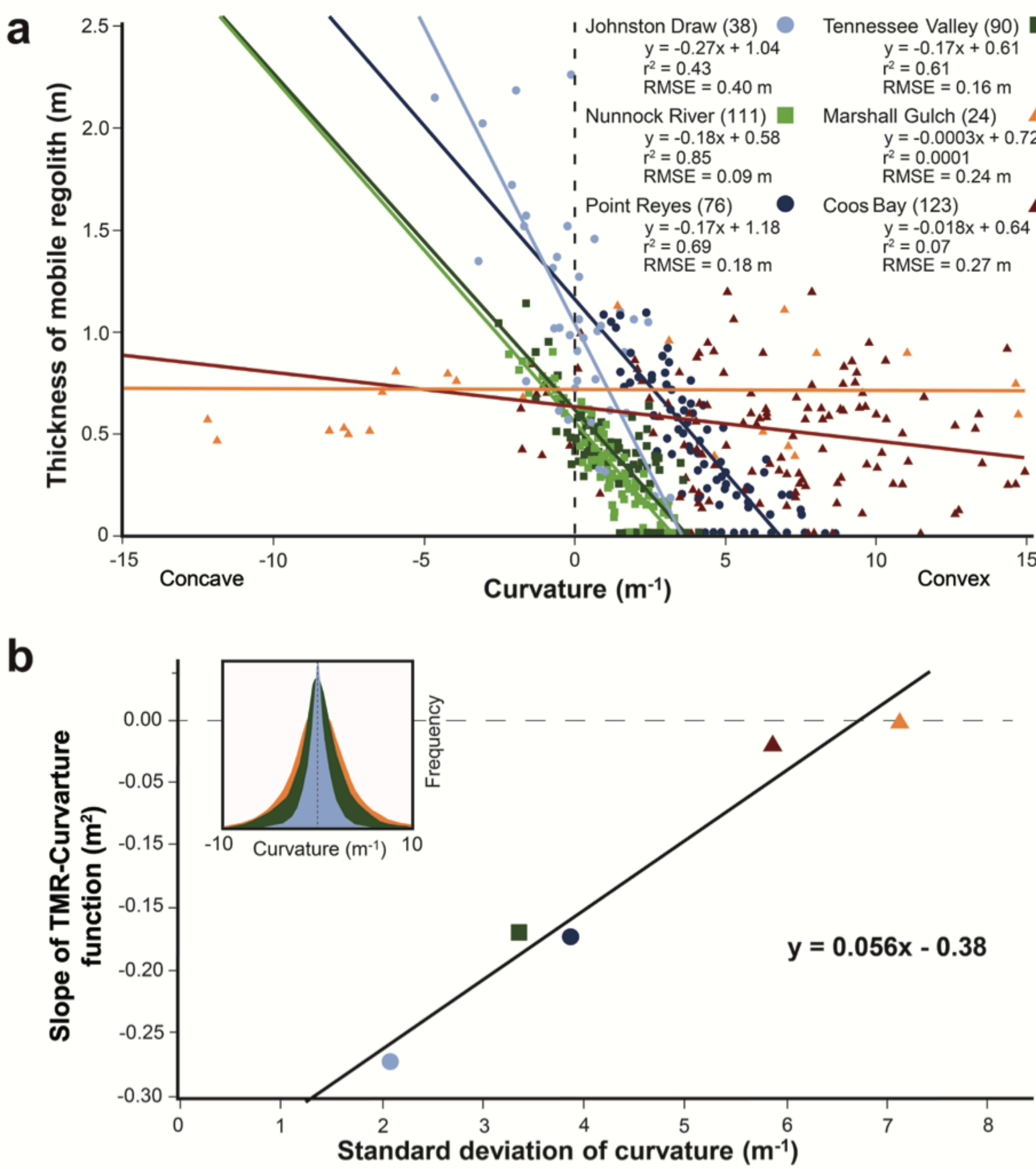


Figure 5: Soil profile total organic carbon, TOC (a) and total nitrogen, TN (b) values, contrasting deep (blue) and shallow (red) soil treatments across all precipitation treatments: ambient (circle), GROW (triangle), and DORM (square).

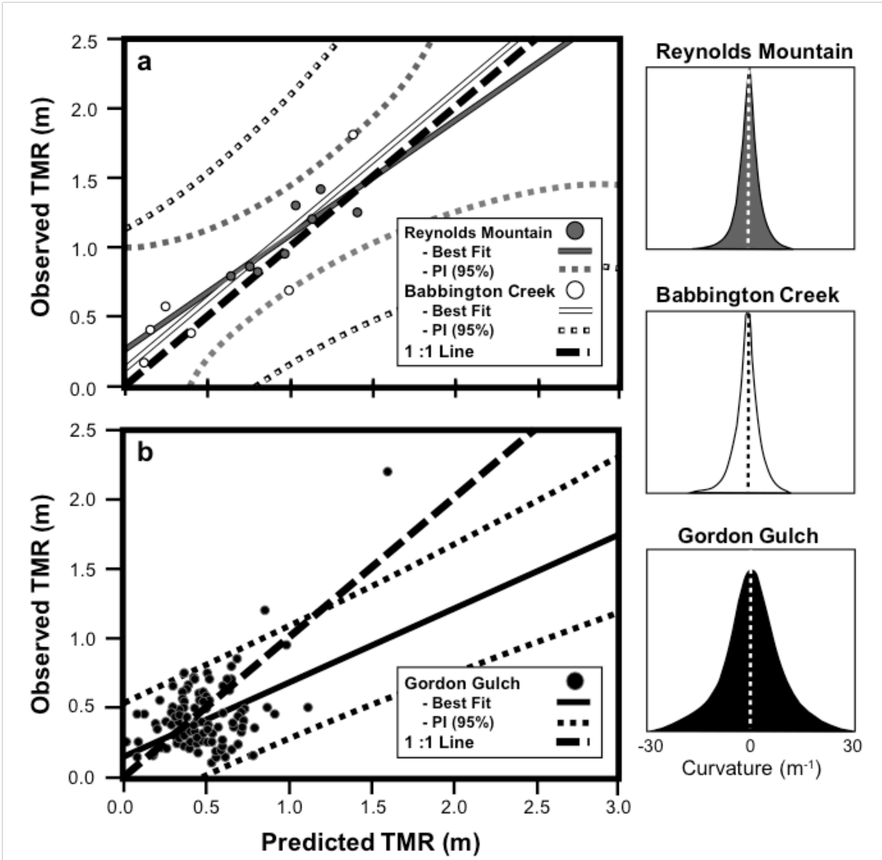
Year 4 Key Outcomes Figures



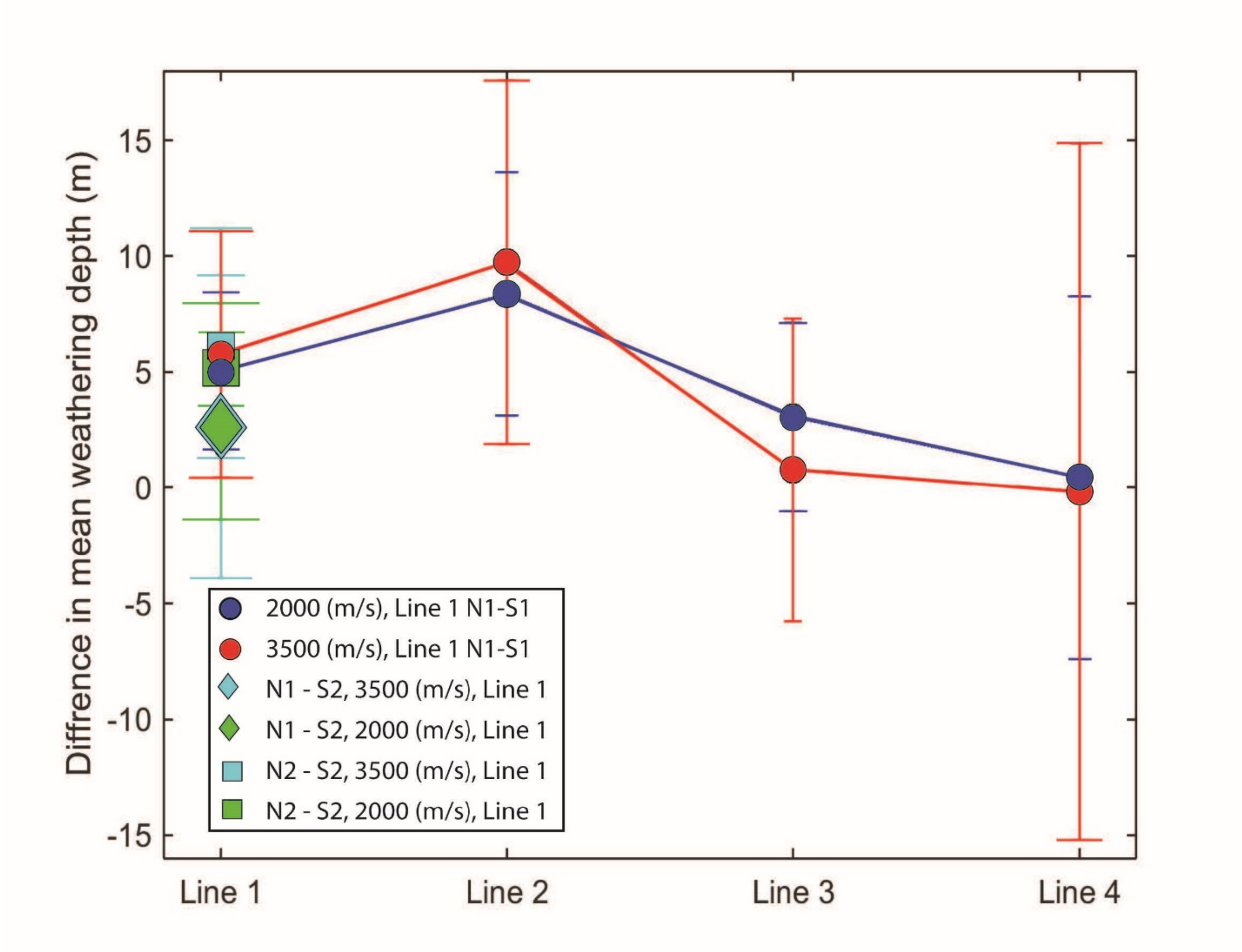
Key Outcome Figure 1: Distributions of normalized snow volume (primary y axes), area (secondary y axes), and vegetation class (inset legends) as a function of normalized elevation for the study sites. The mean winter freezing level (stars), elevation of the 50th percentile of cumulative snow volume (thick vertical line), and the similarity indices (SI) are also plotted for each site. (Tennant et al. 2017, Cross CZO activity)



Key Outcome Figure 2: (A) Cross-site evaluation of six catchments in which the TMR-curvature function is evaluated. (B) Cross-site comparison of the slope of the TMR-curvature function and the local roughness quantified as the standard deviation in curvature. Inset shows curvature distributions based on a 3 m DEM for Johnston Draw (orange), Tennessee Valley (blue), and Marshall Gulch (green) centered on 0 m^{-1}. Nunnock River dataset was not included in (B) due to the lack of high resolution LiDAR data; curvature estimates for Nunnock River in (A) were derived from local observations reported in Heimsath et al. (2001) (Patton et al. in review)



Key outcome Figure 3. Validation of the TMR-curvature approach at Babbington Creek and Reynolds Mountain, Idaho (A) and Gordon Gulch, Colorado, USA (B). Solid white, gray, and black lines represent best-fit predicted vs. observed TMR values based on curvature calculated from a LiDAR-derived DEM and a single soil pit for Babbington Creek, Reynolds Mountain, and Gordon Gulch respectively. Large dashed black lines represent a 1:1 predicted versus observed line. The best-fit slopes were not significantly different from one for Babbington Creek ($|t|=0.01<$critical $t_{0.05,5}=2.571$) and Reynolds Mountain ($|t|=0.86<$critical $t_{0.05,7}=2.365$), indicating unbiased models, whereas the slope was significantly lower than one for Gordon ($p<0.001$, $|t|=-5.73<$critical $t_{0.05,162}=1.974$), indicating over-prediction with higher TMR than observed. Small white, gray, and black dotted lines represent the 95% prediction intervals (PI) (Patton et al. in review)



Key Outcome Figure 4: The N-S weathering depth asymmetry, i.e. the difference in mean depth to fractured (2000m/s) and fresh (3500m/s) bedrock between the north and south facing slopes. Because Line 1 spans two catchments there are two sets of hillslopes to analyze: they are shown as circles for the difference between hillslopes N1 and S1, diamonds for hillslopes N1 and S2, and squares for hillslopes N2 and S2. The highest N-S weathering depth asymmetry occurs at Line 2, above and below this the asymmetry decreases.

Special Reporting Requirements

Table A: Outcomes and Metrics

Major Priority Area	Activity	Metric	Year 4 Target	Year 4 Accomplished
Strategic Priority 1: ***Landscape Soil Carbon Survey***	**Survey**	Create Soil Map	Year 4 Map Created	Year 4 Maps Created
	Characterization	Environmental Datasets Created	150 soil pits collected & analyzed	463 soil pits collected & 4640 total samples collected and ~1150 total analyzed for SOC)
Strategic Priority 2: ***Environmental Monitoring Network***	**Core Site Creation**	# of sites created	4	4
	Net Ecosystem Exchange	Sites instrumented	4	4 instrumented, 1 to burned sage site (upper sheep))
	Transpiration	Sites instrumented	4	5 (3 sage, 1 conifer, 1 aspen, still waiting on juniper permissions)
	Aboveground Biomass and NPP	Sites instrumented	4	4 sites
	Soil Respiration	Sites instrumented/measure d	2	4 FD & 3 profiles at CORE Sites (soil probes)
	Stream and Groundwater Carbon	Samples Collected	200	500 samples collected
Strategic Priority 3: ***Integrated Modeling Framework***	**Create Fine Resolution Hydroclimate data**	Input datasets created	Completed & DOIs	Completed & DOIs
	Integrated Terrestrial Biosphere Modeling	Modeling framework Created	Biome BGC outputs	Biome BGC outputs
Strategic Priority 4: ***Engagement***	**Stakeholder Engagement**	MOUs established	2	2 (ISU, BSU)
	Active CZO Engagement	CZO working group participation	2	4 (E&O, Website, Q-C, Tree, OM, BGC)
	Resource to broader community	Collaborations with X-CZO and non-CZO researchers	2	5
Strategic Priority 5: ***Public Outreach and Education Activities***	**Education**	Students and post-docs engaged	4	10 students +4 postdocs
	Public Outreach	Outreach events	1	5 (STEM, Environmental Fair, Hydrology Days, Adventure Learning, Voice of Fire (ID Public TV),
Strategic Priority 6: ***Data Management***	**Coordination and Policy Development**	Trainings	1	Creation of DOI compatible spreadsheets
	Data Services and Management	Cumulative unique databases uploaded and accessed (# of times)	50	>100

CZO Network Activities

Network Leadership

- Publications

  Journal article

  Brantley, S., W.H. McDowell, W. E. Dietrich, T.S. White, P. Kumar, S. Anderson, J. Chorover, K. Lohse, R. C Bales, D. deB. Richter, G. Grant, J. Gaillardet (In review) Designing a network of critical zone observatories to explore the living skin of the terrestrial *Earth Earth Surface Dynamics*

CZO Network Strategic plan by CZO PIs (including Lohse and Seyfried)

Lohse lead integration of CZ Science in Landscape Management at All Hands Meeting and then is leading review of CZ science that addresses critical zone services and constraints on ecosystem services as part of seminar in Advanced Topics in Biogeochemistry at ISU.

Community CZ Modeling Platform

Reynolds Creek CZO is leading as a testbed for the CZ modeling community. Reynolds Creek CZO has served as a platform for at least modeling studies, including: (1) a partnership with terrestrial ecosystem modelers at the University of Montana described in more detail below, (2) activities conducted in support of an NSF INSPIRE grant to improve representation of hydrologic processes in the global land model CLM (Ying Reinfelder, Rutgers University, PI), (3) application of the reactive transport version of the Pennsylvania Integrated Hydrologic Model (RT-PIHM) for cross-site experiments being led by Li Li (Penn State University), and 4) IML CZO modeling activities with EC tower data. The EC tower data from RC CZO are available on Ameriflux and an additional 108 downloads by modelers from around the world are using these data as there is a paucity of publicly available flux tower data over rangeland systems. Current and future activities are facilitated because the Reynolds Creek CZO leadership has placed significant effort towards: (1) documenting and making datasets rapidly available to the community, (2) developing formal and informal collaborations across CZOs, CZO-like platforms, and CZ modelers, and (3) communicating key unresolved CZ science questions for which Reynolds Creek is particularly well suited to addressing and that cannot be addressed, except through establishing teams of investigators that can apply, test, and refine their models using Reynolds Creek CZO data. Flores has been actively engaging with colleagues in the CZO, LTER, NEON, and CSDMS communities to continue to build a community of practice organized around modeling. This will culminate in two activities during Year 5. First, several CZO, LTER, International Soil Modeling Constortium, and NEON scientists are organizing a modeling workshop for February 2018. The workshop seeks to: (1) identify the key overarching science questions and vision that potentially link these related, but distinct networks, (2) identify gaps between modeling capabilities and needs and develop short, intermediate, and long-term activities that can serve to fill those gaps, and (3) develop a vision for long-term engagement between these communities and how they engage with other key stakeholders like the global land modeling community. Second, Flores is working with Nicole Gapsarini (Tulane U.), Greg Tucker (CU Boulder, BC-CZO, CSDMS), and Erkan Istanbulluoglu (U. Washington) to develop and offer a short course on developing rapid prototypes of models of key critical zone processes to advance understanding of coupling between CZ processes, enable testing of hypotheses that can only be done across sites, and guide subsequent observational and monitoring needs. This workshop will gather approximately two early career scientists (with preference given to graduate students and postdocs) from each CZO and five "at large" early career CZ scientists to learn the LandLab platform, a modeling framework to construct models in Python and using CUAHSI Hydroshare infrastructure. LandLab is a flexible platform, developed with support of an NSF Software Infrastructure for Sustained Innovation, that allows users to construct models by abstracting key processes (e.g., fluvial erosion, diffusive erosion, vegetation dynamics) to function calls that the user can include in constructing a model. It was constructed using modern software practices, allowing for reproducible workflows, user-friendly documentation, and tracking of model provenance.

Working groups (WG)

- CZO PI committee
  - Monthly PI meeting attended by Lohse and Seyfried
- Cross CZO Biogeochemistry
  - Lohse collected 2 full soil profiles in June 2016 for cross site microbial community analysis
  - Lohse contributed to manuscript on 10 big questions in Biogeochemistry in the critical zone (Aug 2017)
- Cross-CZO –Hydrology
  - Godsey submitted paper to special issue on concentration discharge relationships (Oct 2017)
  - Fellows et al. submitted paper to special issue on hydrology in CZO
- Cross CZO - Exploring Four Critical Puzzles Workshop
  - Godsey participated in writing paper as product (see Brantley et al. 2017)
- Cross-CZO Education and outreach committee
  - Lohse was the PI representative for CZOs and attended monthly meetings for the Education and Outreach
  - Virtual Watershed Tour
    - Videos were collected and interviews conducted this summer (June 13-25th, 2016 (20-30 participants) at RC CZO to produce a Virtual Watershed Tour (14 videos) on subwatershed research topics as part of a SAVI/RC CZO funded outreach/education effort.
    - Our data manager produced website that is available for all CZOs to link their videos.
- Cross-CZO Website committee
  - Lohse was the PI representative for CZOs and attended monthly meetings for the Education and Outreach

Meetings

- *CZO PI meetings –Lohse and Seyfried attending monthly meetings*
- *Lohse, Seyfried, Tennant attended reverse site visit in DC in November 2016*
- *Lohse and Seyfried attended PI meeting at AGU in December 2016,*
- *Lohse, Seyfried, Flores, Patton, Sharma, attended the All Hands Meeting in DC in June 2017*
- *Lohse gave a invited talk at the Gordon Research Conference focused on Boundaries and Interfaces in Hydrology and Biogeochemistry and Critical Zone Science featured prominently*
- *Lohse gave a invited plenary talk at the SEG-AGU Imaging the Critical Zone Geophysics Workshop in July 2017*
- *Lohse is attending the NCALM meeting November 9, 2017*
- *Lohse, Seyfried, and Flores attended the Eel River CZO meeting in September 2017*
- *Plant as Plumbers in the Critical Zone* organized by Lohse (RC CZO), Shirley Kurc, Diana Karwan are convened AGU Fall 2017 meeting.
- *Connectivity and runoff generation*. 2016 AGU session convened by Godsey
- Community Surface Dynamics Modeling System (CSDMS) Annual Meeting

  Flores and graduate student Gelb attended the CSDMS meeting in Boulder, CO in May. Both participated in a session on modeling in support of CZ science and attended the Landlab training session, organized by Greg Tucker (BC). Gelb will be using Landlab to address the role of climate, climate change, and disturbance in soil formation and landform development.
- Weather Research and Forecasting (WRF) Data Assimilation (DA) and Regional Climate Modeling tutorial
  - Flores and graduate student Watson attended the WRFDA and Regional Climate tutorial in Boulder, CO in July. Watson will be using WRFDA to identify science requirements for retrievals of falling snow rate from satellites. Flores' CAREER grant uses WRF as a regional climate modeling tool.

Cross CZO Research

Chris Tennant, graduate student at ISU and now postdoctoral associate at UC Berkeley, published a cross CZO analysis examining the the influence of elevation, aspect, and forest cover on the spatial distribution of seasonal snow accumulation using snow-on, snow-off Light Detection and Ranging (LiDAR) data from five Critical Zone Observatory (CZO) sites across the western U.S (Tennant et al. 2017). A SAVI grant from the NO also facilitated this research and collaborations with A. Harpold (U of Nevada, Reno). This cross-site comparison allowed for the first time empirical evaluation of the generality of the snow-elevation relationships and role of hypsometry in controlling snow storage.

K. Lohse and Nick Patton participated in cross Biogeochemistry collection of soil for microbial analyses, and Aho participated in workshop at the Ecological Society of America. Lohse contributed to Big questions in Biogeochemistry (in progress, Lohse contribution)

Nick Patton, K. Lohse, S. Godsey, B. Crosby and M Seyfried integrated published BC CZO and JRB CZO mobile regolith data into paper evaluating the generality of curvature-soil depth relationships (Patton et al. in review)

Godsey engaged in cross CZO synthesis workshop:

Lohse participated on writing a synthesis paper on designing the future CZ science:
Brantley, S., W.H. McDowell, W. E. Dietrich, T.S. White, P. Kumar, S. Anderson, J. Chorover, K. Lohse, R. C Bales, D. deB. Richter, G. Grant, J. Gaillardet (In review) Designing a network of critical zone observatories to explore the living skin of the terrestrial *Earth Earth Surface Dynamics*

Danny Marks, ARS is leading real-time simulation of snow deposition, melt, snow density distribution, over a large region in the Sierra Nevada, integrated with time-series LiDAR measurement of snow depth to improve water supply forecasting during the extreme drought in California.

RC CZO hosted Giova Mosquera, University of Cuenca, Ecuador, for a visit to our National All Hands meeting in Virginia. Potential collaborators from Ecuador.

Cross CZO Publications and Awards
Godsey, S., Idaho State University, NSF CAREER: Active Learning Across Interfaces: Controls on Flow Intermittency and Water Age in Temporary Streams

Brantley, S. L., Eissenstat, D. M., Marshall, J. A., Godsey, S. E., Balogh-Brunstad, Z., Karwan, D. L., Papuga, S. A., Roering, J., Dawson, T. E., Evaristo, J., Chadwick, O., McDonnell, J. J., and Weathers, K. C.: Reviews and syntheses: On the roles trees play in building and plumbing the Critical Zone, Biogeosciences Discuss., https://doi.org/10.5194/bg-2017-61, in review, 2017.

Brantley, S., W.H. McDowell, W. E. Dietrich, T.S. White, P. Kumar, S. Anderson, J. Chorover, K. Lohse, R. C Bales, D. deB. Richter, G. Grant, J. Gaillardet (In review) Designing a network of critical zone observatories to explore the living skin of the terrestrial *Earth Earth Surface Dynamics*

Yang, et al [including Lohse] Ten critical questions in biogeochemistry in the critical zone. To be submitted by Dec 1. (as part of BGC workshop)

Tennant, C.J., Harpold, A.A., Lohse, K.A., Godsey, S.E., Crosby, B.T., Larsen, L.G., Brooks, P.D., Van Kirk, R.W., Glenn, N., 2017. Regional sensitivities of seasonal snow cover to elevation, aspect, and vegetation structure in western North America, Water Resources Research.

Perdrial, Julia; Brooks, Paul; Swetnam, Tyson; Lohse, Kathleen; Rasmussen, Craig; Litvak, Marcy; Harpold, Adrian; Zapata-Rios, Xavier; Broxton, Patrick; Mitra, Bhaskar; Meixner, Thomas; Condon, Katherine; Huckle, David; Stielstra, Clare; Vazquez-Ortega, Angelica; Lybrand, Rebecca; Holleran, Molly; Orem, Caitlyn; Pelletier, Jon; Chorover, Jon. In revision. Climate and landscape as drivers of carbon storage in forested headwater catchments: Insights from a complete C budget" Biogeochemistry

RJ Sindelar, graduate student from MSU, produces 13 videos for a Virtual Watershed website that was also produced as part of 4 yr products (reynoldcreekczo.org/wordpress). This website is available for other CZOs to replicate.

SUMMARY OF SIGNIFICANT FINDINGS

1) Unique benchmark datasets document historical shifts in the snow to rain transition (Kormos *et al*., 2016, Kormos *et al.,* in review, Godsey *et al.,* in review, Enslin *et al.,* 2016)
2) Basin and Range ecosystems such as RC CZO are most sensitive to changes in climate owing to their shortest distance to freezing level; snow depth vary with elevation, vegetation and aspect (Tennant *et al.,* 2017).
3) Geophysics studies reveal that average depth to the top of unweathered bedrock and the depth to the top of fractured bedrock increases with decreasing elevations. The largest difference in weathering depth between the two aspects occurred where the difference in snow accumulation was the greatest (Nielsen 2017, Nielsen *et al.,* in preparation).
4) Fine scale variability in soil temperature associated with aspects rival climate variation observed along elevation gradient (Seyfried *et al*., 2016)
5) Simple empirical soil thickness model enables prediction of soil thickness with minimal measurements and lidar data across a range of lithologies and climate (Patton *et al*., *in review*).
6) Models were developed that accurately distribute SOC and total N from the soil surface to saprolite across complex terrain (r^2=0.82) indicating processes responsible for carbon sequestration in soils vary spatially at relatively small scales (Patton *et al.,* in review). The importance of SOC stored relatively deep in the soil profile, with about half the total catchment SOC was found at depths greater than 0.3 m.
7) Soil inorganic carbon (SIC) stored in drylands is vastly under-estimated in carbon budgets. A new method to quantify the amount stored on coarse fraction (rock) was developed and at Reynolds Creek can explain up to 40% of total SIC (Stanbery *et al*., 2017).
8) Sagebrush steppe ecosystems switch from carbon neutral to carbon sink with increasing elevation and the threshold for this elevation switch depends on annual precipitation (Flerchinger *et al*., *in review)*. Post- snowmelt rainfall exerts strong control on control on gross primary production in sagebrush whereas snowmelt timing controls gross primary production (leaf out) of aspen (Fellows *et al.,* in review).
9) Soil organic carbon in sagebrush steppe ecosystems in arid and warmer environments (Flats) is more sensitive than montane environments to decomposition under varying temperature changes, and accessibility rather than recalcitrance determines sensitivity (Delvinne *et al*., *in review*)
10) Nitrogenase activity by biological soil crusts (BSCs) varies seasonally and with elevation but is highest at the lower elevations, and N fixing bacterial communities associated with BSC switched from cyanobacteria to symbiotic N fixers (Schwabedissen *et al.,* 2017, Blay et al. 2017; Schwabedissen *et al.,* in review).

BROADER IMPACTS

1) Significant interactions between climate and both grazing and shrub-canopy treatments were present. Grazing practices at higher elevations has no significant effect on rates of nitrogenase activity whereas lower elevation sites appeared more sensitive to grazing with declines in activity and changes in microbial community, especially at the plant-canopy scale (Blay et al. 2017, Schwabedissen et al. 2017, Schwabedissen et al. in review). Other landscape legacies such as fire are poorly constrained at this site.
2) Gross productivity in montane sagebrush ecosystems recovers rapidly (within year) following prescribed fire (Fellows *et al.,* in review).

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SUMMARY PROPOSAL BUDGET

ORGANIZATION Idaho State University	PROPOSAL NO.	DURATION (MONTHS)	
		Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Kathleen Lohse	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior List each separately with name and title. (A.7. Show number in brackets)	NSF-Funded Person-months CA	ACA	SUMR	Funds Requested By Proposer	Funds Granted by (If
1. Kathleen Lohse			0.75	$7,606	$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. ( ) TOTAL SENIOR PERSONNEL (1-6)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. ( ) POSTDOCTORAL ASSOCIATES					
2. (1.5) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12/ 6			$67,531	
3. ( ) GRADUATE STUDENTS				$6,427	
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)					
6. ( ) OTHER					
TOTAL SALARIES AND WAGES (A + B)				$81,563	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				$31,608	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				$113,172	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				7000	
2. FOREIGN					
F. PARTICIPANT SUPPORT 1. STIPENDS $ ______ 2. TRAVEL ______ 3. SUBSISTENCE ______ 4. OTHER					
TOTAL NUMBER OF PARTICIPANTS (2) TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$9000	
2. PUBLICATION/DOCUMENTATION/DISSEMINATION				$2000	
3. CONSULTANT SERVICES					
4. COMPUTER SERVICES				$4,500	
5. SUBAWARDS				**$152,440**	
6. OTHER Tuition					
TOTAL OTHER DIRECT COSTS				$167,940	
H. TOTAL DIRECT COSTS (A THROUGH G)				**$287,612.03**	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) 47% on salary only					
TOTAL INDIRECT COSTS (F&A)				$38,335	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**$325,947**	

<table>
<tr><td colspan="3">K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)</td><td></td><td></td></tr>
<tr><td colspan="3">L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)</td><td>$325,947</td><td>$</td></tr>
<tr><td>M. COST SHARING: PROPOSED LEVEL $</td><td colspan="4">AGREED LEVEL IF DIFFERENT: $</td></tr>
<tr><td>PI/PD TYPED NAME AND SIGNATURE*
Kathleen Lohse</td><td>DATE
9/1/16</td><td colspan="3">FOR NSF USE ONLY
INDIRECT COST RATE VERIFICATION</td></tr>
<tr><td>ORG. REP. TYPED NAME & SIGNATURE*</td><td>DATE</td><td>Date Checked</td><td>Date of Rate Sheet</td><td>Initials-ORG</td></tr>
</table>

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*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

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SUMMARY PROPOSAL BUDGET

ORGANIZATION USDA ARS (SUBAWARD)				PROPOSAL NO.	DURATION (MONTHS)	
					Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR MarkSeyfried/ Kathleen Lohse				AWARD NO.		

FOR NSF USE ONLY

A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior List each separately with name and title. (A.7. Show number in brackets)	NSF-Funded Person-months CA	ACA	SUMR	Funds Requested By Proposer	Funds Granted by (If
1					$
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)					
7. ( ) TOTAL SENIOR PERSONNEL (1-6)					
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POSTDOCTORAL ASSOCIATES	12				
2. (1) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	12			$55909	
3. ( ) GRADUATE STUDENTS					
4. ( ) UNDERGRADUATE STUDENTS					
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)					
6. ( ) OTHER				28500	
TOTAL SALARIES AND WAGES (A + B)				$84,409	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				18,540	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				$102,949	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT					
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				2000	
2. FOREIGN					
F. PARTICIPANT SUPPORT 1. STIPENDS $ 2. TRAVEL 3. SUBSISTENCE 4. OTHER					
TOTAL NUMBER OF PARTICIPANTS ( ) TOTAL PARTICIPANT COSTS					
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				$3500	
2. PUBLICATION/DOCUMENTATION/DISSEMINATION					
3. CONSULTANT SERVICES					
4. COMPUTER SERVICES					
5. SUBAWARDS					
6. OTHER Station fees				$8500	
TOTAL OTHER DIRECT COSTS				12000	
H. TOTAL DIRECT COSTS (A THROUGH G)				$116,949	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) 11.1111 of total%					
TOTAL INDIRECT COSTS (F&A)				$12,981.34	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				$129,930.34	

K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)	$129,930.34	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT: $			
PI/PD TYPED NAME AND SIGNATURE* Kathleen Lohse	DATE 9/1/16	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-ORG

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*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

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SUMMARY PROPOSAL BUDGET

ORGANIZATION Boise State University (SUBAWARD)				FOR NSF USE ONLY PROPOSAL NO.	DURATION (MONTHS) Proposed	Granted
PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR Lejo Flores/ Kathleen Lohse				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PIs, Faculty and Other Senior List each separately with name and title. (A.7. Show number in brackets)	NSF-Funded Person-months CA	ACA	SUMR	Funds Requested By Proposer	Funds Granted by (If	
1					$	
2.						
3.						
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)						
7. ( ) TOTAL SENIOR PERSONNEL (1-6)						
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POSTDOCTORAL ASSOCIATES				6000		
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)						
3. (1) GRADUATE STUDENTS						
4. () UNDERGRADUATE STUDENTS						
5. ( ) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)						
6. ( ) OTHER						
TOTAL SALARIES AND WAGES (A + B)				6000		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				3000		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				9000		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)						
TOTAL EQUIPMENT						
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)						
2. FOREIGN						
F. PARTICIPANT SUPPORT 1. STIPENDS $ 2. TRAVEL 3. SUBSISTENCE 4. OTHER						
TOTAL NUMBER OF PARTICIPANTS (5) TOTAL PARTICIPANT COSTS				10000		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES						
2. PUBLICATION/DOCUMENTATION/DISSEMINATION						
3. CONSULTANT SERVICES						
4. COMPUTER SERVICES						
5. SUBAWARDS						
6. OTHER Tuition						
TOTAL OTHER DIRECT COSTS						

H. TOTAL DIRECT COSTS (A THROUGH G)	**$19000**	
I. INDIRECT COSTS (F&A) (SPECIFY RATE AND BASE) 39% MDTC on **$9000**		
TOTAL INDIRECT COSTS (F&A)	$3,510	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)	**$22,510**	
K. RESIDUAL FUNDS (IF FOR FURTHER SUPPORT OF CURRENT PROJECT SEE GPG II.D.7.j.)		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)	**$22,510**	$

M. COST SHARING: PROPOSED LEVEL $	AGREED LEVEL IF DIFFERENT: $			
PI/PD TYPED NAME AND SIGNATURE* Kathleen Lohse	DATE 9/1/16	**FOR NSF USE ONLY** INDIRECT COST RATE VERIFICATION		
ORG. REP. TYPED NAME & SIGNATURE*	DATE	Date Checked	Date of Rate Sheet	Initials-ORG

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*SIGNATURES REQUIRED ONLY FOR REVISED BUDGET (GPG III.C)

BUDGET JUSTIFICATION IDAHO STATE UNIVERSITY (YR 5)
PERSONNEL
PI. Associate Professor Kathleen Lohse is the Director of the Reynolds Creek CZO and responsible for coordination of the research, communications with NSF and oversee management. Lohse co-leads with Seyfried at ARS as deputy director to ensure quality of field data collections and coordination of data. Lohse requests 0.75 month of summer salary in yr 5.

Research specialist (Emma McCorkle) is working 100% time to manage research field and data collected by CZO. We are also requesting 6 months salary at full-time for Sue Parsons on the CZO. She has been acting CZO data manager but leveraged on EPSCoR funds that ends May 2018. Funds will bridge May to Dec funding and she will facilitate making data accessible to public.
Students: We request $6,427 to cover summer salary to cover graduate summer salary (12 wk, 30 hr at $17.8/hr)

FRINGE
21% of salaries and wages for all full-time employees (Lohse and other personnel with 3% increase each year). 8.9% of salaries and wages for all part-time employees (less than 50% time). Students are considered part-time employees. Insurance is applied for non-faculty, non-student individuals, based on percentage of effort and a 10% increase for preceding years for projected inflation, $ 9100 for year 2016-2017.

EQUIPMENT

TRAVEL
Funds ($5k, total) are requested to support for interstate travel and truck rental to field sites at Reynolds Creek, ID, and lodging near site and meetings. In addition, travel will support national conference travel and lodging fees for 2 students and/or faculty. Funds are also requested for the required CZO meeting, $2000 ($7000 total).

PARTICIPANT SUPPORT
We request no participant support.

OTHER DIRECT COSTS
Computer fees: Funds $4.5k yr 5 for Amazon Cloud Server

Materials and Supplies: This category includes costs for research materials and supplies ($9k yr 5). Funds will cover the cost of field and lab supplies include: gloves, specimen cups, weigh tins, soil corers, plastic bags, infiltrometers, filters and collection bottles, vials, coolers, ice, dry ice, standards, pipettors, pipette tips, glass and plastic ware, filters, and reagents. In yr 4, materials and supplies will also cover material and supplies for litter quality characterization, calibration of TLS and spectrometer, litterfall trap, litter bag construction, soil protein characterization, soil enzyme assays, well plates, soil organic matter pool characterization, assays and soil organic matter mineralization, plastic bags, gas, needles, syringes, vials, septa, standards, glassware, tubing, and valves to construct incubation flasks. Sample fees include >2000 C and N mass and isotopic analysis of soil and litter ($5/sample, CAMAS, ISU, nutrient analysis ($6/sample, Lohse ISU), cations ($10/sample), basic physio-chemical characterizations, exchangeable cations ($20/sample (supplies and analysis), anions ($17/sample, Lohse ISU), TOC/TN analysis ($10/sample, Lohse ISU), tissue analyses on Elemental analyzer ($2.5/sample)

Publications: We request $2000 in yr 5 for publication costs.

Subawards: We request $22,510 to BSU and $129,930.34 to USDA ARS for yr 5

Indirect Costs: ISU charges 47% on wages and salaries only and no additional indirects on subawards

BOISE STATE UNIVERSITY SUBAWARD BUDGET JUSTIFICATION
PERSONNEL
PI Subaward. Assistant Professor Lejo Flores is an ecohydrologist and modeler and will be responsible for the model testing and integration. Flores will supervise a PhD graduate student with Dr. Benner at BSU. Flores will oversee subaward and be responsible for coordination of the research with ISU.
Other Personnel:
Postdoctoral associate. Additional salary ($6k) is requested for postdoctoral associate (TBA) in yr 5.
FRINGE
50% of salaries and wages for postdoctoral associates
OTHER DIRECT COSTS
Participant support. We request $10k for modeling workshop
GRA Tuition:
Travel. Not funds are requested to support for interstate and out of state travel and truck rental to field sites at RC CZO and lodging near site and meetings in yr 5.
Materials and Supplies. No funds are requested in yr 5
Indirect Costs at BSU is 39% on MDTC.

USDA-ARS SUBAWARD BUDGET JUSTIFICATION
<u>PERSONNEL</u>
<u>Other Personnel</u>:
<u>Term Research Technician</u> (TBA). A research technician will be hired during of the project and not longer. (Term employees are hired only for a specified time allotment with no assurance of future employment). The primary tasks of the technician will be to assist with instrument installation and field sample collection, maintain/replace CZO field equipment, collect field data and perform routine field sample processing.
Other: We request funds for temporary positions (LA) to fund graduate student summer salary
<u>FRINGE</u>
Employee fringe rate is 21%.
OTHER DIRECT COSTS
<u>Equipment</u>
None.
<u>Travel</u>. Funds ($2000 in yr 5) is requested for the Co-lead PI and RCEW site leader to attend CZO meetings and national conferences.
<u>Participant Support</u>
We do not request participant support
<u>Materials and Supplies</u>. This category includes costs for research materials and supplies at $3.5k in yr 5. This includes funds for five soil CO_2 probes ($650/probe) and field and lab supplies include: gloves, calibrants, weigh tins, soil augers, corers, plastic bags and infiltrometers.
<u>Publications</u>
<u>Station Fees</u> We request $8.5k in station fees to cover cleaning and other maintenance fees
<u>Indirect Costs</u> at USDA ARS is 11.111% on total.

Additional Funding

Godsey, S., Idaho State University, NSF CAREER: Active Learning Across Interfaces: Controls on Flow Intermittency and Water Age in Temporary Streams

Pierce, J., N. Glenn, E. Yager. 2015-2016, $46,724, Boise State University, RAPID: An Integrated Study of Post-fire Wind and Water Erosion in Western Rangelands

ISU Graduate School, ISU funded 20 semester hours of Graduate Teaching Assistantships to Lohse (through negotiation) as part of her CZO award to offset the $2.5 M reduction in CZO budget. This has funded 2 graduate students during the academic year at ISU to conduct research at Reynolds Creek CZO. Summer salaries have been covered by CZO.

Seyfried, M., $40,000 Department of Interior, Bureau of Land Management, Develop and test a user interface for the Soil Ecohydrology Model to be used for estimating forage production on semiarid rangelands.

USDA ARS Northwest Watershed Research Center (NWRC), $414,700. The ARS NWRC has contributed $224, 200 in Scientific Personnel, $150,500 in Support Personnel, $35,000 to Range building improvement (projected), and $5000 to road improvements.

Long Term Agroecosystem Research Network (LTAR) funds, $50,000. The NWRC became part of the USDA sponsored Long Term Agricultural Ecosystem (LTAR) network in 2014. There is considerable overlap in the type of research undertaken by the two networks. Approximately $20,000 of scientific equipment was purchased that will serve both projects out of a total of about $50,000 that will go towards research that is complimentary to the goals and objectives of the RC CZO.

Flores, L. 5-year, $457,205 NSF CAREER Award *Citizens, Conservation, and Climate: Research and Education for Climate Literacy in Managed Landscapes*. This project investigates the role of land management policies and activities in meeting multiple and potentially competing objectives. Modeling tools include models that explicitly simulate land management activities undertaken by land management agencies under alternative hypothetical scenarios, and regional climate models (WRF) to assess the feedbacks of those management activities to regional hydroclimate. Importantly, it also includes an education program consisting on developing a k-12 teacher education program to support climate literacy in Idaho. The program uses open source electronics (e.g., Arduino, Raspberry Pi, etc.) and sensors to learn about climate, computer science, and electrical engineering. Rangelands are specifically mentioned in the grant as a target region, where grazing, fire, climate change, and invasive species interact to “replumb” the hydrologic cycle. The RC-CZO represents an important study site because of the history of investigating the influence of land management on ecohydrology.

Glenn, N. and A.N. Flores, $748,000 NASA Terrestrial Ecology grant, start date January 2014, *Scalable vegetation structure for ecosystem modeling in the western US*. Glenn and Flores were awarded a 3-year that focuses on developing new methods for quantifying ecosystem structure and function with LiDAR and hyperspectral remote sensing. This information will be used to parameterize a shrubland ecosystem input for the Ecosystem Demography model. Reynolds Creek is one of 5 study sites in the Great Basin covering Idaho and California. In August 2014, NASA JPL's Airborne Snow Observatory (ASO) collected LiDAR with a Riegl Q1560 instrument. NASA JPL's AVIRIS-ng hyperspectral system is expected to collect imagery in September 2014 at all study sites, including Reynolds. The RC CZO ecosystem studies will benefit from these imagery and field data collections in a number of ways. For example, Glenn and Flores have a student (Ilangakoon) working on biomass and canopy cover of different vegetation communities at the study sites using LiDAR and hyperspectral data. In addition, Glenn and Flores have a student who will be testing appropriate scale and derivatives of remote sensing products for parameterizing a shrubland component in Ecosystem Demography.

Flores and Glenn, along with HP Marshall and Jim McNamara, were awarded a 3-year, $750,000 NASA EPSCoR grant *Monitoring Earth's Hydrosphere Integrating Remote Sensing, Modeling, and Verification*. The project aims to improve spatiotemporal predictions of precipitation, soil moisture, snow water storage, and runoff using remote sensing inputs for the Weather Research and Forecasting (WRF) model. The project will be mutually beneficial to the RC CZO. First, the RC CZO represents an important study site where independent verification of estimated hydrometeorologic variables (e.g., precipitation amount and phase, wind speed, radiant fluxes, temperature, etc.). Furthermore, the development of these data assimilation techniques will lead to hydrometeorologic forcing datasets that are constrained to available remote sensing data and are spatiotemporally complete during periods for which boundary condition data required as input to WRF are available.

Flores along with, H.P. Marshall, Kelly Elder (US Forest Service) were awarded a 3-year $300,000 grant *Multiple frequency active microwave remote sensing for snow water equivalent retrieval from space: a data* *assimilation approach* via the NASA Terrestrial Hydrology Program. This project will develop improved retrievals of snow water equivalent using a combination of modeling and remote sensing resources. Specifically, the effort targets the use of active microwave (i.e., radar) observations at several different wavelengths in an effort to characterize snowpacks. The information is assimilated into land surface models that simultaneously estimate water storages and fluxes in the landscape. RC CZO is explicitly included as a study area in the proposal due to the available infrastructure. Core sites, in particular, will be invaluable for validating estimates of sublimation from snowpacks derived from the model. The efforts will lead to improved snow water equivalent estimates that will benefit hydrologic modeling and analyses in the RC-CZO.

Flores and Godsey are engaged with Idaho's ongoing participation in the EPSCoR Track II program. Specifically, as part of the Western Consortium for Watershed Analysis, Visualization and Exploration the team is developing suites of data management and visualization tools to enable rapid prototyping of watershed models, using existing constitutive models. Specifically, Flores and graduate students are developing scripts to enable the use of output from the Weather Research and Forecasting (WRF) model to be packaged and used as input to finer-scale watershed models, specifically focusing on the ParFlow model. Godsey, Prof. Shannon Kobs-Nawotniak are developing a CSDMS wrapper for the iSNOBAL model, to enable it to more readily interface with other component models. Observational infrastructure at RC CZO will support validation and verification of model estimates. Moreover, the data management and visualization infrastructure will more broadly benefit modeling at RC CZO and across CZOs by providing and using software infrastructure to quickly develop models of critical zone processes to address cross-CZO science questions.

Pending

Lohse, K, M. Seyfried, F. Pierson, A. Flores. Construction of a Living and Education Facility at the Reynolds Creek Experimental Watershed Field Station, $750,000 (not funded submission 12/9/16, resubmit 12/9/17)

-This proposal is aimed at improving living and education facilities at Reynolds Creek Experimental Watershed Field Station given the increase in visitors/yr.

Lohse, K., M. Seyfried, S. Holbrook, Scott Miller. Deep couplings of water and rock in the critical zone. IES. Projected. Nov 30, 2017

Konings A, Saatchi S, Ramirez C, Slaton M, Koltunov A, Judge J, Novick K, **Reinhardt K**. May 2017. NASA ROSES (Research Opportunities in Earth and Space Science) Program: A canopy water content ESDR for monitoring global biosphere stress. $2.7m requested ($13k ISU). In review.

-This proposal was submitted to fund applied remote-sensing research, aimed at developing an existing remote sensing product for an additional application (monitoring plant water stress). This includes ground-truthing of plant water stress with satellite fly-overs, which is my component of the project.

Reed, S. et al. USGS. Grazing and climate change interact to affect dryland carbon cycling via effects on plants, biological soil crusts, and soils, NASA Roses

Reed, S. et al. USGS. Grazing and climate change interact to affect dryland nitrogen cycling via effects on