ESSD-2019-182 - AUTHORS' RESPONSES TO REVIEWER COMMENTS ON " *VEGETATION, GROUND COVER, SOIL, RAINFALL SIMULATION, AND OVERLAND FLOW EXPERIMENTS BEFORE AND AFTER TREE REMOVAL IN WOODLAND-ENCROACHED SAGEBRUSH STEPPE: THE HYDROLOGY COMPONENT OF THE SAGEBRUSH STEPPE TREATMENT EVALUATION PROJECT (SAGESTEP)*" - WILLIAMS ET AL

- **Reviewer comments are in bold font and author responses are in normal font.**
- **Page and line number references in author responses are to the revised manuscript unless otherwise noted.**
- **Author specific responses to Reviewer comments are numbered sequentially relative to the entire list of responses.**

RESPONSES TO ANONYMOUS REFEREE #1 COMMENTS:

1. **Williams et al. provide an important and highly valuable contribution to plot-scale experiments on runoff and soil erosion in the semi-arid Great Basin, USA. Up to my best knowledge, this is the most extensive data set currently available. These data are important to parameterize commonly applied runoff and soil erosion models, such as RHEM. While I am convinced that this data set is highly relevant for a wide array of scientific disciplines for model applications and hypothesis testing, there are several suggestions [that] I'd like to point out.**

   The authors appreciate the comments here regarding the importance and value of this extensive dataset and its potential applications. We also thank the reviewer for the numerous suggestions, addressed below in respective responses.

2. **The main section on 'Study sites and Experimental design' is hard to follow. Maybe the authors could better link the descriptions to Table 2 provided in the manuscript.**

   Labelling omissions in Table 2 (for each of the black filled rows) of the original submission are the source of the confusion noted here by Reviewer 1. Reviewers 2 and 3 also pointed out confusion with Table 2 linkage to the "Study Sites and Experimental Design" section. Reviewer 3 specifically noted the lack of labels for the four sections in Table 2 (see comment #24 below). We provide a corrected Table 2 in revision, with the labels for each section. The same table is archived in the correct form (with all labels) with the original dataset at the required data repository (https://doi.org/10.15482/USDA.ADC/1504518), US Department of Agriculture, National Agricultural Library, Ag Data Commons website (https://data.nal.usda.gov/).

   Each of the four sections in Table 2 (separated by the black filled rows) is associated with a specific plot type (site characterization vegetation plots, small rainfall plots, large rainfall plots, or overland flow plots) and provides the number of respective plots by plot type for each study site for each Year × Treatment × Microsite combination. Table 2 therefore provides an overview of the study design across sites for each of the plot types and is important in understanding the information presented in the “Study Sites and Experimental Design” section. Collectively, Figures 1 and 2 provide visual examples of the rainfall simulation experiments, instrumentation, and associated microsites, and Tables 1 and 2, respectively, provide site descriptions for the three sites and the distribution of plots by plot type across study years and treatments. The omissions of labels in the black rows (for the sections) of Table 2 greatly affect this linkage. The corrected Table 2 provides the necessary clarity and linkage requested here by Reviewer 1 and the other reviewers in subsequent comments below (comment #9 by Reviewer 2 and comment #24 by Reviewer 3).

3. **In the field methods section, the authors did explain how foliage is estimated. I was wondering if the foliage is as static as described here or if foliage does differ over the seasons? In that case, additional information on the season the experiment was conducted should be provided.**

   All measurements were made in the summer season each sampling year, but that was not explicitly stated in the original manuscript. In revision, we replaced the text “The data were collected in years 2006-2015…” with “All data were collected in summer months in the years 2006-2015…” to clarify the season of measurement, as suggested by Reviewer 1 here. This revision is located at Lines 131-132 in the revised manuscript.

   Foliage can vary across seasons on rangelands and at the sites in this study, as suggested by Reviewer 1 here. Our experiments provide foliage measures taken at the same point in time (summer season) as the hydrology and erosion experiments to address the controls/drivers of hydrologic and erosion responses and to assess the impacts of tree removal on vegetation as measured in the summer season. The research was not meant to characterize seasonal variation in foliage throughout each of the study years.

4. **The applied rainfall intensities are assumed to reflect the natural rainfall distributions. However, the data from rain gauges close to the experimental sites is not shown. I suggest to include such a graph. It is well established that rainfall simulations often exceed natural rainfall intensities, sometimes up to an order of magnitude. This conflict complicates the transfer from small-scale findings to natural systems, e.g. modeling studies often on a larger spatial scale. Regardless, the authors should better explain their choice of rainfall intensities. Sometimes higher-than-natural intensities are intentionally chosen to amplify hydrological responses on diverse environmental settings.**

   As noted by Reviewer 1, rainfall intensities in rainfall simulation experiments are typically applied at rates intended to exceed infiltration capacity and generate runoff. Without runoff, the infiltration capacity before runoff generation remains unknown, and predictive utility of the data is somewhat limited. Further, treatment effects studies, such as this one, commonly select rainfall rates that stress the system of study in order to evaluate treatment effectiveness in buffering runoff and erosion. Our selection of rainfall rates was based on these typical experimental requirements of rainfall simulation studies, which are well documented in the literature (as noted by the reviewer; see response to comment #5 below for list of studies with similar methodologies). We provided return intervals for rainfall events in our previous papers on the dataset, but omitted them here in attempt to limit duplication of text from our previous papers describing the methods. The journal editors required us to minimize repeating methodologies explicitly described in our associated publications on the experiments, and to, instead, simply cite those studies. We therefore provided references to the original papers that contain these details (see Lines 272-277 in the original and revised manuscripts). The rainfall intensity for the dry-run simulations over 5-min, 10-min, and 15-min durations is equivalent to respective storm return intervals of 7 yr, 15 yr, and 25 yr. The wet – run intensity over 5-min, 10-min, and 15-min durations is equivalent to respective storm return intervals of 25 yr, 60 yr, and 120 yr. These return intervals are based on the NOAA precipitation-frequency atlas of the United States (NOAA Atlas 14, Volume 1, Version 4.0) (as cited in Pierson et al., 2010 and other publications noted at Lines 272-277 in the original manuscript). There are no rainfall gauges at the study sites specifically for intensity derivations. Of most importance for users of the data in modelling is knowledge of the rainfall rate applied; the plot vegetation, ground cover, and soil characteristics; and runoff/erosion rates. All of these measures are provided in the various tables. We are willing to add the above rainfall return-interval information to the revised manuscript if desired by the journal editors pending their requirements to limit duplication of methods specificity from the long list of associated publications on the experiments (see also response to comment #22 below for list of publications from the dataset).

5. **The authors state that ‘wet’ simulations are conducted on plots where rainfall was applied for the previous dry runs. The time lag between both runs (dry vs. wet) is 30 min (lines 274-275). While I see the general and often unavoidable restrictions with such difficult and comprehensive experiments, I was wondering if this experimental design is really appropriate. Given the first dry run preceding the wet run, one could expect that all fine, and thus, mobile soil sediment has been evacuated during the dry run and, consequently, the wet runs may be more supply limited than the previous dry run. Did the authors account for such potential shift in the soil erosion regime? The authors could, for example, provide exemplary sediment hysteresis to test for this. I am convinced that such a graph would add a lot of relevant information.**

   The dry- and wet-run methodologies applied in our experiments are common for rainfall simulation studies, largely for logistical reasons as pointed out by Reviewer 1. The multiple intensities on a plot allow for more replications and for assessment of responses across different rainfall rates and/or soil wetness conditions without additional laborious installations, plot characterizations, and moving/setting up of rainfall simulators. The list of studies utilizing such efficiencies is long (abbreviated list spanning five decades is provided here, excludes papers by authors associated with this study: Blackburn, 1975; Roundy et al., 1978; Johnson and Blackburn, 1989; Simanton et al., 1991; Johansen et al., 2001; Pierson et al., 2002; Stone et al., 2008; Polyakov et al., 2018).

   As Reviewer 1 points out, some wet-run erosion rates in this study may have been affected by respective dry-run simulations with runoff (typical to these type of experiments). In some cases, dry-run simulations yielded zero runoff and likely posed little to no impact on wet-run sediment discharge rates (with exception of wetter soils). Rainfall simulation data reported in tables for our experiments do not account for carryover effects between dry-run and wet-run simulations. Our data tables do report whether runoff occurred for the dry- and wet-run simulations for each rainfall simulation plot. Dry-run simulation carryover effects on erosion from wet-runs could be modelled on that basis, as suggested by Reviewer 1. However, we simply elect to provide full description of the methodologies employed and the actual time series data. Our goal is to provide an extensive dataset and allow users to utilize the dataset for respective applications, rather than to provide a full suite of analyses of the data. Our approach here is consistent with a similar extensive rainfall simulation database recently published in ESSD by Polyakov et al. (2018). It is impractical to conceive of all possible uses and applications and to account for all respective potential data amendments. Given the methodological explanations, a user can opt to include or exclude various components of the dataset as appropriate for the associated application, inclusive of any analyses required for such an assessment.

We have added the following text, at Lines 440-445 in the revised manuscript, to ensure data users recognize the potential for carryover effects from the dry-run to wet-run simulations and for overland flow experiments:

> "Time series runoff and sediment data provided for rainfall simulations and overland flow experiments do not account for carryover effects from one plot run to the next on a given plot in a given year (i.e., dry-run effects on wet-run simulations; effects of 15 L min^{-1} overland flow releases on subsequent 30-45 L min^{-1} overland flow releases). Data users should consider whether carryover effects impact respective applications and make applicable adjustments to acquired data."

Blackburn, W. H. (1975), Factors influencing infiltration and sediment production of semiarid rangelands in Nevada. *Water Resources Research*, *11*(6), 929-937.

Johansen, M. P., Hakonson, T. E., & Breshears, D. D. (2001), Post-fire runoff and erosion from rainfall simulation: Contrasting forests with shrublands and grasslands. *Hydrological Processes*, *15*(15), 2953-2965.

Johnson, C. W., & Blackburn, W. H. (1989), Factors contributing to sagebrush rangeland soil loss. *Transactions of the American Society of Agricultural Engineers*, *32*(1), 155-160.

Pierson, F. B., Spaeth, K. E., Weltz, M. A., & Carlson, D. H. (2002), Hydrologic response of diverse western rangelands. *Journal of Range Management*, *55*(6), 558-570.

Polyakov, V., Stone, J., Collins, C. H., Nearing, M. A., Paige, G., Buono, J., & Gomez-Pond, R. L. (2018), Rainfall simulation experiments in the southwestern USA using the Walnut Gulch Rainfall Simulator. *Earth System Science Data*, *10*(1), 19-26. doi: 10.5194/essd-10-19-2018.

Roundy, B. A., Blackburn, W. H., & Eckert R.E., J. (1978), Influence of prescribed burning on infiltration and sediment production in the pinyon-juniper woodland, Nevada. *J. Range Manage.*, *31*(4), 250-253.

Simanton, J. R., Weltz, M. A., & Larsen, H. D. (1991), Rangeland experiments to parameterize the water erosion prediction project model: vegetation canopy cover effects. *Journal of Range Management*, *44*(3), 276-282.

Stone, J. J., Paige, G. B., & Hawkins, R. H. (2008), Rainfall intensity-dependent infiltration rates on Rangeland rainfall simulator plots. *Transactions of the ASABE*, *51*(1), 45-53.

6. **By inspecting the data sets available for downloading, I saw that many of the experiments were restricted to 45 minutes (e.g. small_time_series-csv). May the authors explain such time restriction?**

The duration for each rainfall simulation was set to 45 min for experimental and logistical purposes. The authors have extensive experience conducting rainfall simulations (for example see Pierson et al., 2001, 2002a, 2002b, 2008a, 2008b, 2009). Based on that experience, we found that steady state infiltration and runoff generally occur within 45 min for most rainfall simulation applications at moderate to high rainfall intensities. Of course, infiltration for a given rainfall intensity varies with soil properties, surface conditions, and vegetation cover. We anticipated the 45 min duration would allow enough time for steady state infiltration and runoff on most of our plots, particularly for the highest intensity. Steady state infiltration and runoff were not always achieved with our design, and, in some cases, no runoff occurred. This is common for experiments that span the variability in conditions encountered in our experiments. The 45 min duration was also selected so that we could achieve the required replications across the various Site × Treatment × Microsite combinations each field season. The selected duration is similar to durations used in numerous other rainfall simulation studies (see short list of studies cited below and in comment #5 above for example), typically in the range of 30 min to 60 min. There is no need to state such a justification in the manuscript given our approach is typical for rainfall simulation experiments and that the duration is provided in the methods description.

Pierson, F. B., Bates, J. D., Svejcar, T. J., & Hardegree, S. P. (2007), Runoff and erosion after cutting western juniper. *Rangeland Ecology and Management*, *60*(3), 285-292.

Pierson, F. B., Carlson, D. H., & Spaeth, K. E. (2002a), Impacts of wildfire on soil hydrological properties of steep sagebrush-steppe rangeland. *International Journal of Wildland Fire*, *11*(2), 145-151.

Pierson, F. B., Moffet, C. A., Williams, C. J., Hardegree, S. P., & Clark, P. E. (2009), Prescribed-fire effects on rill and interrill runoff and erosion in a mountainous sagebrush landscape. *Earth Surface Processes and Landforms*, *34*(2), 193-203. doi: 10.1002/esp.1703.

Pierson, F. B., Robichaud, P. R., Moffet, C. A., Spaeth, K. E., Hardegree, S. P., Clark, P. E., & Williams, C. J. (2008a), Fire effects on rangeland hydrology and erosion in a steep sagebrush-dominated landscape. *Hydrological Processes*, *22*(16), 2916-2929. doi: 10.1002/hyp.6904.

Pierson, F. B., Robichaud, P. R., Moffet, C. A., Spaeth, K. E., Williams, C. J., Hardegree, S. P., & Clark, P. E. (2008b), Soil water repellency and infiltration in coarse-textured soils of burned and unburned sagebrush ecosystems. *Catena*, *74*, 98-108.

Pierson, F. B., Robichaud, P. R., & Spaeth, K. E. (2001), Spatial and temporal effects of wildfire on the hydrology of a steep rangeland watershed. *Hydrological Processes*, *15*(15), 2905-2916. doi: 10.1002/hyp.381.

Pierson, F. B., Spaeth, K. E., Weltz, M. A., & Carlson, D. H. (2002b), Hydrologic response of diverse western rangelands. *Journal of Range Management*, *55*(6), 558-570.

7. Lastly, while I highly appreciate the efforts the authors put into the generation of this data set, I was wondering how these data relate to previous studies conducted in other study areas but the ones presented here. Do the authors see the chance to use and/or transfer their data set for studies outside the Great Basin area?

The data presented in this manuscript were collected in support of research on conifer encroachment and various practices to arrest tree advance and infill in Great Basin sagebrush steppe. Woody plant encroachment is occurring on water-limited sparsely-vegetated landscapes around the World. Typically, as woody plants encroach, herbaceous vegetation declines, the plant community structure coarsens, and connectivity of bare ground and runoff and sediment sources increases (Schlesinger et al., 1990; Wainwright et al., 2000; Turnbull et al., 2009, 2012; Williams et al., 2014). These changes commonly result in elevated runoff and erosion rates and long-term loss of ecologically important surface soil. Without management intervention or natural disturbance, such plant community transitions can become self-perpetuating (Turnbull et al., 2012). These structural and functional relationships are consistent with woodland encroachment effects on the sites in this dataset and with the ecohydrologic responses to management that the dataset spans (e.g., Pierson et al., 2010; Williams et al., 2014, 2016, 2019a, 2019b, 2020). Trends in runoff and erosion rates associated with wildfire and land use induced changes in vegetation, groundcover, and soils generally follow similar trends as those across our dataset (Cerdà and Doerr, 2005; Ludwig et al., 2005, 2007; Turnbull et al., 2010; Moody et al., 2013). Given these fundamental relationships, we anticipate that our dataset is applicable in forecasting potential relative changes in runoff and erosion under similar plant community dynamics. It is intuitive that actual runoff and erosion rates and vegetation responses to treatments may vary for different climate, soil, topographic, and other site-specific attributes in other domains. The dataset also transfers for use in evaluating/validating predictive capability of and potentially enhancing runoff and erosion models developed for water-limited lands such as rangeland and woodlands on sloping topography (e.g., Al-Hamdan et al., 2012, 2015). The points presented here are retained from the original Abstract (now at Lines 31-39) and Summary and Conclusions (now at Lines 470-481).

Al-Hamdan, O. Z., Hernandez, M., Pierson, F. B., Nearing, M. A., Williams, C. J., Stone, J. J., Boll, J., & Weltz, M. A. (2015), Rangeland Hydrology and Erosion Model (RHEM) enhancements for applications on disturbed rangelands. *Hydrological Processes*, *29*(3), 445-457. doi: 10.1002/hyp.10167.

Al-Hamdan, O. Z., Pierson, F. B., Nearing, M. A., Williams, C. J., Stone, J. J., Kormos, P. R., Boll, J., & Weltz, M. A. (2012), Concentrated flow erodibility for physically based erosion models: Temporal variability in disturbed and undisturbed rangelands. *Water Resources Research*, *48*(7). doi: 10.1029/2011WR011464.

Cerdà, A., & Doerr, S. H. (2005), Influence of vegetation recovery on soil hydrology and erodibility following fire: An 11-year investigation. *International Journal of Wildland Fire*, *14*(4), 423-437.

Ludwig, J. A., Bartley, R., Hawdon, A. A., Abbott, B. N., & McJannet, D. (2007), Patch configuration non-linearly affects sediment loss across scales in a grazed catchment in north-east Australia. *Ecosystems*, *10*(5), 839-845. doi: 10.1007/s10021-007-9061-8.

Ludwig, J. A., Wilcox, B. P., Breshears, D. D., Tongway, D. J., & Imeson, A. C. (2005), Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes. *Ecology*, *86*(2), 288-297.

Moody, J. A., Shakesby, R. A., Robichaud, P. R., Cannon, S. H., & Martin, D. A. (2013), Current research issues related to post-wildfire runoff and erosion processes. *Earth-Science Reviews*, *122*, 10-37. doi: 10.1016/j.earscirev.2013.03.004.

Pierson, F. B., Williams, C. J., Kormos, P. R., Hardegree, S. P., Clark, P. E., & Rau, B. M. (2010), Hydrologic vulnerability of sagebrush steppe following pinyon and juniper encroachment. *Rangeland Ecology and Management*, *63*(6), 614-629. doi: 10.2111/rem-d-09-00148.1.

Schlesinger, W. H., Reynolds, J. F., Cunningham, G. L., Huenneke, L. F., Jarrell, W. M., Virginia, R. A., & Whitford, W. G. (1990), Biological feedbacks in global desertification. *Science*, *247*(4946), 1043-1048.

Turnbull, L., Wainwright, J., & Brazier, R. E. (2008), A conceptual framework for understanding semi-arid land degradation: ecohydrological interactions across multiple-space and time scales. *Ecohydrology*, *1*(1), 23-34.

Turnbull, L., Wainwright, J., Brazier, R. E., & Bol, R. (2010), Biotic and Abiotic Changes in Ecosystem Structure over a Shrub-Encroachment Gradient in the Southwestern USA. *Ecosystems*, *13*(8), 1239-1255. doi: 10.1007/s10021-010-9384-8.

Turnbull, L., Wilcox, B. P., Belnap, J., Ravi, S., D'Odorico, P., Childers, D., Gwenzi, W., Okin, G., Wainwright, J., Caylor, K. K., & Sankey, T. (2012), Understanding the role of ecohydrological feedbacks in ecosystem state change in drylands. *Ecohydrology*, *5*(2), 174-183. doi: 10.1002/eco.265.

Wainwright, J., Parsons, A. J., & Abrahams, A. D. (2000), Plot-scale studies of vegetation, overland flow and erosion interactions: case studies from Arizona and New Mexico. *Hydrological Processes*, *14*(16-17), 2921-2943.

Williams, C. J., Pierson, F. B., Al-Hamdan, O. Z., Kormos, P. R., Hardegree, S. P., & Clark, P. E. (2014), Can wildfire serve as an ecohydrologic threshold-reversal mechanism on juniper-encroached shrublands. *Ecohydrology*, *7*(2), 453-477. doi: 10.1002/eco.1364.

Williams, C. J., Pierson, F. B., Kormos, P. R., Al-Hamdan, O. Z., Nouwakpo, S. K., & Weltz, M. A. (2019a), Vegetation, Hydrologic, and erosion responses of sagebrush steppe 9 yr following mechanical tree removal. *Rangeland Ecology and Management*, *72*(1), 47-68. doi: 10.1016/j.rama.2018.07.004.

Williams, C. J., Pierson, F. B., Nouwakpo, S. K., Al-Hamdan, O. Z., Kormos, P. R., & Weltz, M. A. (2020), Effectiveness of prescribed fire to re-establish sagebrush steppe vegetation and ecohydrologic function on woodland-encroached sagebrush rangelands, Great Basin, USA: Part I: vegetation, hydrology, and erosion responses. *Catena*, *185*. doi: 10.1016/j.catena.2018.02.027.

Williams, C. J., Pierson, F. B., Nouwakpo, S. K., Kormos, P. R., Al-Hamdan, O. Z., & Weltz, M. A. (2019b), Long-term evidence for fire as an ecohydrologic threshold-reversal mechanism on woodland-encroached sagebrush shrublands. *Ecohydrology*, *12*(4). doi: 10.1002/eco.2086.

Williams, C. J., Pierson, F. B., Robichaud, P. R., Al-Hamdan, O. Z., Boll, J., & Strand, E. K. (2016), Structural and functional connectivity as a driver of hillslope erosion following disturbance. *International Journal of Wildland Fire*, *25*(3), 306-321.

RESPONSES TO ANONYMOUS REFEREE #2 COMMENTS:

8. **The manuscript presents extensive data on numerous parameters characterizing surface and shallow subsurface hydrology at three locations within the western U.S. These data are concise and relevant for future hydrological and sedimentary analysis, and potential inclusion to various land surface models. The manuscript is available for download via the URL provided by the authors.**

   We appreciate Reviewer 2's comments here regarding the extensiveness and relevancy of the dataset.

9. **The description of plot scales should be consistent throughout the manuscript. In the Abstract, only 'overland flow' plots are mentioned explicitly; this changes to rainfall simulations at various plot sizes and overland flow plots in Lines 111-113, and finally to four plot scales in Lines 148-150, hillslope plots added. Besides, a small figure showing locations for each plot could be useful for non-U.S. readership. This inconsistency is brought further to the text, Section 3, where field methods description starts with hillslope-scale plots, the largest, and continues with small- and large-scale plots etc. Though there might be a certain logic in such description order, I would suggest to follow either top-down or bottom-up approach.**

   We appreciate Reviewer 2 bringing this to our attention. We believe the bulk of the confusion is associated with the aforementioned omissions of labels (showing various plot scales) in Table 2 (see response to Reviewer 1 comment #2 above). We have corrected Table 2 to show the labels, as discussed in above comment #2 response, and that revision should provide clarity regarding the various plot scales.

   As for the abstract, we initially avoided specific information on various plot scales to simply focus on processes, which have a scale dependency. We considered methods in the abstract abbreviated, but added detail given the issue presented. To address confusion, we added specific details to the abstract text regarding the various plots with runoff and erosion measurements, following the top-down approach (at Lines 27-31):

> "The methodologies applied in data collection and the cross-scale experimental design uniquely provide scale-dependent, separate measures of interrill (rainsplash and sheetflow processes, 0.5 m^2 plots) and concentrated overland-flow runoff and erosion rates (~9 m^2 plots), along with collective rates for these same processes combined over the patch scale (13 m^2 plots)."

At lines 148-150, we clearly specify each of the plot types and the respective scales in a top-down model as suggested by the reviewer, and follow that text with basic experimental design presentation and explanation of what is measured at each plot scale throughout the rest of the section (with multiple references to corrected Table 2). We did re-arrange the paragraph text to ensure the text follows the scale presentation of the opening sentence, Lines 148-150 that read:

> "A suite of biological and physical attributes at each site were measured at point, small-rainfall plot (0.5 m^2), overland-flow plot (~9 m^2), large-rainfall plot (13 m^2), and hillslope plot (990 m^2) scales."

The "Field Methods" section (Section 3) provides the explanation of sampling methods by plot type. There, we do begin with the hillslope scale plots simply because those only include vegetation and ground cover measures. All of the other plot types include vegetation, ground cover, soil, and hydrology/erosion measures. Also, there is some practical groupings of the small plot and large plot rainfall simulations (due to similarities in methods across the scales) and then presentation of the overland flow methods. This methodological presentation was used in nearly all of the published papers (15+) on the dataset and was retained for continuity with those papers. This may be particularly useful if a user is going back to these papers for more specific details on the various methods. This presentation also clearly separates the various methodologies by respective plot scales.

The corrections to Table 2 (see response to comment #2 above for Reviewer 1), amendments to the abstract noted above, and clear description of the various plot scales in Section 2 (Lines 148-150) remedy the issue presented here by Reviewer 2. Additionally, we have made multiple minor text insertions to clarify measurement scales in various areas of the manuscript.

Reviewer 2 also suggests a figure showing the various plot locations, but the number of plots across the sites, study years, treatments, etc. would be very cumbersome for a reader (too many symbols, etc.). However, we do agree that adding the site locations would potentially be helpful for a non-US reader. We have added latitude and longitude information in for each site, underneath the site names/locations in Table 1. A reader can easily enter these numbers into Google Earth or another mapping software to see the study site locations and visualize the sites to the degree possible by the selected software.

10. **Lines 287-288, the sediment concentration is said to be calculated from runoff samples by weighing; what is a 'runoff sample'? Is it a liquid volume - and if yes, was it just dried to full sample evaporation? If not, was any filtration system used, and if yes, then what were its parameters - pore size etc?**

    The runoff samples were indeed liquid samples as is generally intuitive for runoff samples. Each sample was collected in the field in a numbered sample bottle and was retained in that sealed bottle for processing at the laboratory. Each runoff sample (water, sediment, and bottle) was weighed in the laboratory and the mass was recorded. Each bottle (with all water and sediment retained) was then placed in an oven set at 105° C and left in the oven until all water was evaporated. Each bottle was then removed from the oven, reweighed, and the remaining mass (sample bottle and sediment) was recorded. Each bottle was then washed of all sediment, air dried, and then weighed to determine the bottle tare mass. For each sample, the mass of water from the original runoff sample was calculated by subtracting the respective mass of the dry sediment and sample bottle from the combined total mass of the water, sediment, and sample bottle. Likewise, the sediment mass for each sample was calculated by subtracting the respective sample bottle tare mass from the measured mass of the respective dry sediment and sample bottle. Runoff samples were not filtered at any stage of laboratory processing. The above described methodology is considered a standard laboratory procedure for these types of experiments and is more simply described by the current text in the manuscript, with exception perhaps of the lack of filtering. Filtering is sometimes used to reduce sample drying times, but we did not employ this method. Our current statement regarding processing of samples is typical for runoff sample processing and is a generally accepted statement for publication given the standard methods. However, we have now clarified samples were not filtered. The full text referenced here by Reviewer 2 and the addition of new text on filtering now reads (at Lines 287-289):

    > "Cumulative runoff and sediment amounts were obtained for each runoff sample by weighing the sample before and after drying at 105°C (Pierson et al., 2010). Runoff samples were not filtered at any stage of laboratory processing."

11. **The dataset is well-organized, but several technical corrections are needed:**

    Each of the items presented by Reviewer 2 are addressed in the responses below (comments #12-#18).

12. **Section 3.1. Data Dictionary - data types should be presented as standard notation, i.e. integer, real, character etc; same, variable sizes should be given, i.e. as INT/LONG INT/DOUBLE/CHAR(X) etc.**

    We appreciate Reviewer 2's comment here regarding the data structure and considered recoding the data structure, including the associated variable items. In short, we retained the original data structure in the form required by the approved data repository to minimize confusion across an array of potential end users, as explained here. The final dataset was organized by the authors and submitted to and reviewed by the US Department of Agriculture, National Agricultural Library, Ag

Data Commons (https://data.nal.usda.gov/), an approved data repository for ESSD datasets. The submission was subjected to the requirements by the data repository and the final dataset meets all requirements of the data repository, including the data dictionary and data structure. The dataset has been archived by the data repository and has been assigned a doi (https://doi.org/10.15482/USDA.ADC/1504518). As such, the dataset and its structure have been approved, established, and archived by the data repository in a commonly accepted format. The suggestions here by Reviewer 2 are indeed also common, but are somewhat a component of data application associated with one of an array of potential end users and applications. The needs of end users vary extensively depending on the data application and software applied, as such meeting all potential desired structures is impractical. The dataset items noted here by Reviewer 2 and others noted by Reviewer 2 in subsequent comments below (see comments #13, #14, #17, and #18 below) are all easily addressed by an end user through some simple recoding, typical in downloading and using any dataset. We have elected to retain our approved and archived data structure, per the data repository, in lieu of developing amended versions that may further add confusion associated with archiving duplicative tables and data structures of the same dataset. We see the potential confusion induced by duplicative tables as being more confusing for end users than having the one existing data structure relative to many other possible structures. Further, the data structure is consistent with another recent similar dataset published by ESSD, Polyakov et al. (2018).

Polyakov, V., Stone, J., Holifield Collins, C., Nearing, M. A., Paige, G., Buono, J., and Gomez-Pond, R.-L. (2018), Rainfall simulation experiments in the southwestern USA using the Walnut Gulch Rainfall Simulator. *Earth Syst. Sci. Data*, *10*, 19–26. doi: 10.5194/essd-10-19-2018.

13. **Section 3.2. Categorical variables are multiple in the Data Dictionary, and are particularly poorly described; possible categories are listed as 'Acceptable values', which is not the best way to present them. No explanation on whet does, e.g. 'Tracked_LowMulch' mean, is given in the dataset itself. A separate table explaining your categorical variables is needed, or you might suggest a better way of presentation.**

    Please see our response to Reviewer 2 comment #12 above, which also applies in full to this comment.

14. **Section 3.3. Same, 'Yes/No' is not a character variable, but has LOGICAL type, therefore acceptable values are 0/1, Y/N, or T/F, each is valid.**

    Please see our response to Reviewer 2 comment #12 above, which also applies in full to this comment.

15. **Section 3.4. Dataset contains some info on treatment area and date, but I've found no clear descriptors for treatment type for each dataset in the plot characteristics table. This raises the question on whether the variables are correctly distributed between various dataset tables.**

    The authors do not understand the meaning of this comment. Each of the sub-datasets contain the information for treatment/treatment area, treated (yes or no), and treatment date, as explained here. Table 2 includes a column for treatment for each plot type and shows the number of plots sampled in each treatment for each Site and Site × Microsite combination. All other data tables presented in the paper (Tables 3 and 5-11), with exception of the soil texture and bulk density data table (Table 4), include columns for Treatment/Treatment Area, Treated Yes or No, and Year. The respective tables in the data repository, https://doi.org/10.15482/USDA.ADC/1504518, all contain columns for Treatment/Treatment Area, Treated Yes or No, and Treatment Date. All data and the data structure were evaluated extensively by the authors and the data repository prior to submission and approval for posting by the data repository, as explained in the response to Reviewer 2 comment #12 above.

16. **Section 3.5. Table 3 contains no info on either plot type (small vs large vs overland etc) or plot area.**

    The confusion here stems in part from the lack of labels on Table 2 for the various plot types. Table 3 shows data for the hillslope-scale site characterization plots (990 m^2). The table caption does show the plot type and plot area, contrary to the reviewer comment here, and explains that the data are foliar and ground cover measures. The revised Table 2, showing the associated labels provides additional clarity in addressing this issue (see response to Reviewer 1, comment #2 above).

17. **Section 3.6. I find it difficult to browse through data with visual inspection, since: PLOT_ID is a last column, e.g. in Table 4, and is hard to find in other tables as well; in several tables, PLOT_ID is not unique since two rows contain data for differerent years; treatment date repeats in Tables 3 and 4.**

    Please see our response to Reviewer 2 comment #12 above, which also applies in full to this comment.

18. **In general, column sequence is not entirely logical, and can be enhanced. The dataset structure, I believe, should be subject to technical inspection. I suggest the authors to read your dataset to R/RStudio environment and check dataset usability / statistical analysis performance.**

    Please see our response to Reviewer 2 comment #12 above, which also applies in full to this comment. The data have undergone technical inspection as part of the data repository requirements. There are many different data structures possible to suit various potential data applications and software tools. Multiple data structures (i.e., multiple versions of tables) to accommodate all possible software applications is not merited and perhaps induces more confusion for end users. Some data reorganization to meet end user needs is typical with data extraction from repositories and is readily accomplished through simple coding in various data management software packages, including R.

<u>RESPONSES TO ANONYMOUS REFEREE #3 COMMENTS:</u>

19. **General comments: Authors present extensive and detailed dataset with vegetation, ground cover, soils, hydrology, and erosion data from over 1000 plots in diverse vegetation, ground cover, and surface soil conditions from three study sites in USA for five study years. Presented data is of**

high scientific importance and probable usage in the future. Study sites, experimental design and field methods are well described.

The authors thank Reviewer 3 for these comments regarding the extensiveness, scientific importance, and utility of the dataset.

20. **There are no explicit estimates of the data errors and its discussion. Consider adding some uncertainty estimates in the Section 2 or Section 3.**

    The best estimates of error for the type of measures presented would simply be indicated by variability for each measure. We have elected rather to provide the actual data and allow users to make such evaluations regarding application. The data have been well published in various papers (15+ published papers) as cited in the reference section for the manuscript. As such, assessments that include those measures of variability are readily available through other publications. Our intent here is not to re-analyze these data, but rather to provide the data in full form for use by others. Of course, that assumes end users will make their own assessment on the utility of the dataset for the desired application.

21. **Paper does not provide information about which exactly kind of data is in the dataset. Reader is not able to decide whether he/she interested to download data or not based just on the paper. I suggest including a new section or subsection or extend Section 5 and include brief technical overview of the data covering description of variables from the dataset (maybe in a table that is shorter version of the table "SageSTEP_Database_Data_Dictionary" from the dataset), technical details (could be from lines 450-461) and structure of the data files.**

    Although we appreciate the comment here, we opine this is unnecessary. The dataset has been well published and context for the dataset is well explained in the abstract. There is also a more detailed description of the dataset at the required data repository, https://doi.org/10.15482/USDA.ADC/1504518. We originally included much of that more detailed description in this paper, but were required by the journal editors to reduce that duplicative content. Given the numerous publications from the dataset (15+ papers, see references), the description already available at the data repository, and the abstract here, we do not see clear merit of adding an additional summary as suggested here by the reviewer.

22. **Section 4 is important for understanding of scientific significance of the presented dataset but lacks any scientific conclusions. It explains the previous usage of data. It would be good for readers to know not only descriptions of data usage but also the scientific results. I suggest expanding the section, brief presenting significant findings of the mentioned studies and referring to the Figures 3-5.**

    See response to comment #21 above in this regard. Results from the various data collection studies for the greater dataset presented are well published already in a series of 15+ papers. Repeating those here is duplicative and unnecessary. The series of papers published to date on this dataset span pre-treatment conditions (Pierson et al., 2010, 2013; Williams et al., 2014), initial impacts of tree removal treatments (Cline et al., 2010; Pierson et al., 2014, 2015; Williams et al., 2014, 2016), longer-term impacts of tree removal (Nouwakop et al., 2020; Williams et al., 2019a, 2020), and a full analysis spanning pre-treatment, short-term responses, and long-term responses for tree removal by fire (Williams et al., 2019b). The dataset application in development of hydrology and erosion model parameters has been well published in a suite of papers by Al-Hamdan et al. (2012a, 2012b, 2013, 2015, 2017). Additionally, a manuscript of the research findings spanning the entire study and with additional measurements on long-term soil erosion rates and 13 yr treatment effects is in preparation for submission later this year. Our goal for the current manuscript is simply to provide a basic description of the study, the methods, and the available dataset (with linkage to the required repository), along with some abbreviated presentation on data uses (current Section 4). It is not our intent to re-present analyses and results here, as they stand alone already in the various publications, see list below.

Al-Hamdan, O. Z., Hernandez, M., Pierson, F. B., Nearing, M. A., Williams, C. J., Stone, J. J., Boll, J., & Weltz, M. A. (2015), Rangeland Hydrology and Erosion Model (RHEM) enhancements for applications on disturbed rangelands. *Hydrological Processes*, *29*(3), 445-457. doi: 10.1002/hyp.10167.

Al-Hamdan, O. Z., Pierson, F. B., Nearing, M. A., Stone, J. J., Williams, C. J., Moffet, C. A., Kormos, P. R., Boll, J., & Weltz, M. A. (2012a), Characteristics of concentrated flow hydraulics for rangeland ecosystems: implications for hydrologic modeling. *Earth Surface Processes and Landforms*, *37*(2), 157-168. doi: 10.1002/esp.2227.

Al-Hamdan, O. Z., Pierson, F. B., Nearing, M. A., Williams, C. J., Hernandez, H., Boll, J., Nouwakpo, S. K., Weltz, M. A., & Spaeth, K. E. (2017), Developing a parameterization approach for soil erodibility for the Rangeland Hydrology and Erosion Model (RHEM). *Transactions of the American Society of Agricultural and Biological Engineers*, *60*(1), 85-94. doi: 10.13031/trans.11559.

Al-Hamdan, O. Z., Pierson, F. B., Nearing, M. A., Williams, C. J., Stone, J. J., Kormos, P. R., Boll, J., & Weltz, M. A. (2012b), Concentrated flow erodibility for physically based erosion models: temporal variability in disturbed and undisturbed rangelands. *Water Resources Research*, *48*(7), W07504.

Al-Hamdan, O. Z., Pierson, F. B., Nearing, M. A., Williams, C. J., Stone, J. J., Kormos, P. R., Boll, J., & Weltz, M. A. (2013), Risk assessment of erosion from concentrated flow on rangelands using overland flow distribution and shear stress partitioning. *Transactions of the ASABE*, *56*(2), 539-548.

Cline, N. L., Roundy, B. A., Pierson, F. B., Kormos, P., & Williams, C. J. (2010), Hydrologic response to mechanical shredding in a juniper woodland. *Rangeland Ecology and Management*, *63*(4), 467-477.

Nouwakpo, S. K., Williams, C. J., Pierson, F. B., Weltz, M. A., Arslan, A., & Al-Hamdan, O. Z. (2020), Effectiveness of prescribed fire to re-establish sagebrush steppe vegetation and ecohydrologic function on woodlandencroached sagebrush rangelands, Great Basin, USA:

Part II: Runoff and sediment transport at the patch scale. *Catena*, *185,* 104301. doi: 10.1016/j.catena.2019.104301.

Pierson, F. B., Williams, C. J., Hardegree, S. P., Clark, P. E., Kormos, P. R., & Al-Hamdan, O. Z. (2013), Hydrologic and erosion responses of sagebrush steppe following juniper encroachment, wildfire, and tree cutting. *Rangeland Ecology and Management*, *66*(3), 274-289.

Pierson, F. B., Williams, C. J., Kormos, P. R., & Al-Hamdan, O. Z. (2014), Short-term effects of tree removal on infiltration, runoff, and erosion in woodland-encroached sagebrush steppe. *Rangeland Ecology and Management*, *67*(5), 522-538. doi: 10.2111/rem-d-13-00033.1.

Pierson, F. B., Williams, C. J., Kormos, P. R., Al-Hamdan, O. Z., Hardegree, S. P., & Clark, P. E. (2015), Short-term impacts of tree removal on runoff and erosion from pinyon- and juniper-dominated sagebrush hillslopes. *Rangeland Ecology and Management*, *68*(5), 408-422. doi: 10.1016/j.rama.2015.07.004.

Pierson, F. B., Williams, C. J., Kormos, P. R., Hardegree, S. P., Clark, P. E., & Rau, B. M. (2010), Hydrologic vulnerability of sagebrush steppe following pinyon and juniper encroachment. *Rangeland Ecology and Management*, *63*(6), 614-629. doi: 10.2111/rem-d-09-00148.1.

Williams, C. J., Pierson, F. B., Al-Hamdan, O. Z., Kormos, P. R., Hardegree, S. P., & Clark, P. E. (2014), Can wildfire serve as an ecohydrologic threshold-reversal mechanism on juniper-encroached shrublands? *Ecohydrology*, *7*(2), 453-477. doi: 10.1002/eco.1364.

Williams, C. J., Pierson, F. B., Kormos, P. R., Al-Hamdan, O. Z., Nouwakpo, S. K., & Weltz, M. A. (2019a), Vegetation, hydrologic, and erosion responses of sagebrush steppe 9 yr following mechanical tree removal. *Rangeland Ecology and Management*, *72*(1), 47-68. doi: 10.1016/j.rama.2018.07.004.

Williams, C. J., Pierson, F. B., Nouwakpo, S. K., Al-Hamdan, O. Z., Kormos, P. R., & Weltz, M. A. (2020), Effectiveness of prescribed fire to re-establish sagebrush steppe vegetation and ecohydrologic function on woodland-encroached sagebrush rangelands, Great Basin, USA: Part I: vegetation, hydrology, and erosion responses. *Catena*, *185,* 103477. doi: 10.1016/j.catena.2018.02.027.

Williams, C. J., Pierson, F. B., Nouwakpo, S. K., Kormos, P. R., Al-Hamdan, O. Z., & Weltz, M. A. (2019b), Long-term evidence for fire as an ecohydrologic threshold-reversal mechanism on woodland-encroached sagebrush shrublands. *Ecohydrology*, *12*(4). doi: 10.1002/eco.2086.

Williams, C. J., Pierson, F. B., Robichaud, P. R., Al-Hamdan, O. Z., Boll, J., & Strand, E. K. (2016), Structural and functional connectivity as a driver of hillslope erosion following disturbance. *International Journal of Wildland Fire*, *25*(3), 306-321. doi: 10.1071/WF14114.

23. Table 1: Intercanopy bare ground includes shrubs and grasses?

We appreciate the reviewer pointing this out. “Intercanopy” refers to the area between tree canopies consisting of shrubs, grasses, and interspaces between plants (i.e., shrub-interspace zone).

So, Reviewer 3 is correct here, that intercanopy *bare ground* should not include shrubs and grasses. To correct the error, we have added the text “Intercanopy refers to the….” at the beginning of the footnote referenced by “Intercanopy bare ground (%)[11]”, which now reads:

> “Intercanopy refers to the area between tree canopies consisting of shrubs, grasses, and interspaces between plants (i.e., shrub-interspace zone).”

24. **Table 2: There are 4 parts of the Table. What do they refer to? Consider adding informative titles to different parts of the table and relocate extensive description of different types of sites to the paper text.**

    Please see response to Reviewer 1 comment #2 above, which addresses this issue. We thank Reviewer 3 for pointing this out. We have made the corrections to Table 2 as indicated in response to comment #2.

25. **Line 206: Are site characterization plots representative for all plots at each of three study sites?**

    The authors are not exactly sure of the question here, as the measures for these plots are presented in Section 3.1. The site characterization plots provide measures of hillslope scale vegetation and ground cover in each treatment area at the sites prior to treatments (2006) and in each treatment area at the sites 1 yr post-treatment (2007) and 9 yr post-treatment (2015). Only site characterization data for Marking Corral and Onaqui are shown, see Table 3. The corrections to Table 2 may also alleviate this question (see response to Reviewer 1 comment #2 above).

26. **Lines 450-459: Consider to relocate this detailed description of the dataset from the Conclusions to Section 5 or new Section / subsection with the technical overview of the data.**

    Please see response to Reviewer 3 comment #22 above.

27. **Data table “Small time series”: Please explain what empty cells mean, for example lines No 6099, 7431, 7504, 8349 of the columns “Runoff_L_min”, ”SedConc_g_L”, ”Runoff_mm_hr” and ”SedDisch_g_s”.**

    These are cases in which the runoff sample was discarded due to laboratory or field errors (e.g., bottle spillage). We will work with the data repository to determine the best way to re-code (as missing) or remove these lines for this time series data file, if necessary.

28. **Link to the data DOI in the abstract and Section 5 leads to DOI Not Found webpage.**

    The authors confirmed the link is active and correct. Perhaps there was a temporary outage at the data repository or in the user network at the time access was tested by Reviewer 3.

29. **Line 387-389: It would be useful to show TRAW and width variables on the photo or on the scheme.**

We can understand the utility of such a photo, but find it difficult to clearly identify the full wetted width and individual flow paths widths in the photos as measured at cross-sections 1 m, 2 m, and 3 m downslope from the flow release. However, we provided a detailed diagram of these measures in an earlier paper (Pierson et al., 2008) and have added reference to that paper. The diagram there should provide clarity on the methods without replication of the figure in this publication (which we are trying to avoid per the editorial staff). The text at the noted location now reads, at Lines 388-391:

> "The width, depth, and a total rill area width (TRAW) of overland flow were measured along flow cross-sections 1 m, 2 m, and 3 m downslope from the flow release point (Pierson et al., 2010). The TRAW variable represents the total width between the outermost edges of the outermost flow paths at the respective cross section (see Pierson et al., 2008)."

30. **Figure 3: Do (a) and (c) refer to Marking Corral site and (b) and (d) – to Onaqui site? It should be explicitly noted in the Figure caption.**

    Reviewer 3 is correct here regarding the figure assignments. We have amended the figure caption, as shown below, to clarify the figure assignments:

    > "Figure 3. Example infiltration (a [Marking Corral] and b [Onaqui]), calculated as applied rainfall minus measured runoff, and sediment discharge (c [Marking Corral] and d [Onaqui]) time series data generated from a subset of the small-plot rainfall simulation dataset. Example sub-dataset is from wet-run rainfall simulations in untreated (Cont) and burned (Burn) interspace (Int), shrub coppice (Shr), and tree coppice (Tree) microsites at the Marking Corral and Onaqui study sites 9 yr following prescribed fire. The data illustrate the long-term impacts of burning and associated changes in surface conditions on infiltration and sediment discharge. Figure modified from Williams et al. (2020)."

31. **Untreated tree coppice microsite indicated as bold green line in the legend but dash line on the graph. It would be better to use bold lines for all three control microsites.**

    Reviewer 3 is referring to the lines in Figure 3 and is correct in regards to the error. We have corrected the figure legend to correctly identify each of the lines drawn in the figure. We elected to retain the dash format. Users that print in black and white may need the line variations to correctly separate one line from another. Using all solid lines for controls would hinder such separation in a black and white version.

32. **Table 5-6: expand abbreviations Fol. Cvr., JUOC and WDPT.**

    We reviewed all tables for abbreviation issues and addressed those that were not intuitive. These abbreviations are explained in the data dictionary at the data repository, but we provide them now in the respective table captions for these abbreviated tables. The captions have been revised as shown below:

Table 4. Soil texture and bulk density variables and data structure for those measures for all study sites. Abbreviations in the table example are as follows: juniper_cop refers to juniper coppice microsites; shrub_cop refers to shrub coppice microsites; and pinyon_cop refers to pinyon coppice microsites.

Table 5. Example (subset) of vegetation and ground cover variables and data structure for measures on hillslope-scale site characterization plots (990 m^2) at the study sites. Abbreviations in the table example are as follows: Fol. Cvr. refers to Foliar Cover; and JUOC refers to western juniper (*Juniperus Occidentalis* Hook.).

Table 6. Example (subset) of rainfall simulation, vegetation, ground cover, and soil variables and data structure for measures on small-rainfall simulation plots (0.5 m^2) at the study sites. Abbreviations in the table example are as follows: Fol. Cvr. refers to Foliar Cover; Grd. Cvr. refers to Ground Cover; WDPT refers to Water Drop Penetration Time; shrub_cop refers to shrub coppice microsites; pinyon_cop refers to pinyon coppice microsites; and juniper_cop refers to juniper coppice microsites.

Table 7. Example (subset) of rainfall simulation, vegetation, ground cover, and soil variables and data structure for measures on large-rainfall simulation plots (13 m^2) at the study sites. Abbreviations in the table example are as follows: Fol. Cvr. refers to Foliar Cover; Grd. Cvr. refers to Ground Cover; Avg. refers to average; juniper_cop refers to juniper coppice microsites; and pinyon_cop refers to pinyon coppice microsites.

Table 8. Example (subset) of overland flow, vegetation, and ground cover variables and data structure for measures on overland flow simulation plots (~9 m^2) at the study sites. Abbreviations in the table example are as follows: Avg. refers to average; juniper_cop refers to juniper coppice microsites; and pinyon_cop refers to pinyon coppice microsites.

Table 9. Example (subset) of time series runoff and sediment data from small-plot rainfall simulations (0.5 m^2) at the study sites. Abbreviations in the table example are as follows: Conc. refers to concentration; and shrub_cop refers to shrub coppice microsites.

Table 10. Example (subset) of time series runoff and sediment data from large-plot rainfall simulations (13 m^2) at the study sites. Abbreviations in the table example are as follows: Conc. refers to concentration; and juniper_cop refers to juniper coppice microsites.

Table 11. Example (subset) of time series runoff and sediment data from overland flow simulations (~9 m^2) at the study sites. Abbreviations in the table example are as follows: Conc. refers to concentration; and juniper_cop refers to juniper coppice microsites.

Vegetation, ground cover, soil, rainfall simulation, and overland flow experiments before and after tree removal in woodland-encroached sagebrush steppe: the hydrology component of the Sagebrush Steppe Treatment Evaluation Project (SageSTEP)

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Abstract. Rainfall simulation and overland-flow experiments enhance understanding of surface hydrology and erosion processes, quantify runoff and erosion rates, and provide valuable data for developing and testing predictive models. We present a unique dataset (1021 experimental plots) of rainfall simulation (1300 plot runs) and overland flow (838 plot runs) experimental plot data paired with measures of vegetation, ground cover, and surface soil physical properties spanning point to hillslope scales. The experimental data were collected at three sloping sagebrush (*Artemisia* spp.) sites in the Great Basin, USA, each subjected to woodland-encroachment and with conditions representative of intact wooded-shrublands and 1-9 yr following wildfire, prescribed fire, and/or tree cutting and shredding tree-removal treatments. The methodologies applied in data collection and the cross-scale experimental design uniquely provide scale-dependent, separate measures of interrill (rainsplash and sheetflow processes, 0.5 m^2 plots) and concentrated overland-flow runoff and erosion rates (~9 m^2 plots), along with collective rates for these same processes combined over the patch scale (13 m^2 plots). The dataset provides a valuable source for developing, assessing, and calibrating/validating runoff and erosion models applicable to diverse plant community dynamics with varying vegetation, ground cover, and surface soil conditions. The experimental data advance understanding and quantification of surface hydrologic and erosion processes for the research domain and potentially for other patchy-vegetated rangeland landscapes elsewhere. Lastly, the unique nature of repeated measures spanning numerous treatments and time scales delivers a valuable dataset for examining long-term landscape vegetation, soil, hydrology, and erosion responses to various management actions, land use, and natural disturbances. The dataset is available from the US Department of Agriculture, National Agricultural Library at https://data.nal.usda.gov/search/type/dataset (DOI: https://doi.org/10.15482/USDA.ADC/1504518; Pierson et al., 2019).

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Keywords: ecohydrology; erosion; fire effects; infiltration; overland flow; prescribed fire; rainfall simulation; rangeland hydrology; runoff; sagebrush steppe; tree cutting; tree shredding; tree removal; woody plant encroachment

1 Introduction

Rangelands are one of the most common occurring sparsely-vegetated wildland landscapes around the world. These lands cover about half of the world's land surface and about 31% (> 300 million ha) of the land surface in the US (Havstad et al., 2009). The patchy vegetation structure typical to these water-limited landscapes regulates connectivity of runoff and erosion sources and processes and thus controls hillslope scale runoff and sediment transport (Pierson et al., 1994; Wainwright et al., 2000; Wilcox et al., 2003; Ludwig et al., 2005). Runoff and erosion in isolated bare patches on well-vegetated rangelands occur as splash-sheet (rainsplash and sheetflow) processes. Sediment entrained by raindrops and shallow sheetflow in bare patches typically moves a limited distance downslope before deposition immediately upslope of and within vegetated areas (Emmett, 1970; Reid et al., 1999; Puigdefábregas, 2005; Pierson and Williams, 2016). Disturbances such as intensive land use, plant community transitions, and wildfire can alter this resource-conserving vegetation structure and thereby facilitate increases in runoff and soil loss through enhanced connectivity of overland flow and sediment sources during rainfall events (Davenport et al., 1998; Wilcox et al., 2003; Pierson et al., 2011; Williams et al., 2014a, 2014b, 2018). The negative ramifications of woody plant encroachment and wildfire have been extensively studied on rangelands around the World and this work has advanced understanding of runoff and erosion processes for these commonly occurring ecosystems (Schlesinger et al., 1990; Wainwright et al., 2000; Shakesby and Doerr, 2006; Shakesby, 2011; Pierson and Williams, 2016). Recent widespread plant community transitions and trends in wildfire activity and associated amplified runoff and erosion rates spanning rangelands to dry forests throughout the western US (Williams et al., 2014a) and elsewhere (Shakesby, 2011) underpin a need for compiling data sources that further contribute to process understanding and improved parametrization of rangeland hydrology and erosion predictive technologies.

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Sagebrush rangelands in the western US are an extensive (> 500 000 km^2) and important vegetation type that have undergone substantial degradation associated with encroachment by pinyon (*Pinus* spp.) and juniper (*Juniperus* spp.) woodlands, invasions of fire-prone annual cheatgrass (*Bromus tectorum* L.), and altered fire regimes (Davies et al., 2011; Miller et al., 2011, 2019). Pinyon and juniper woodland encroachment of sagebrush vegetation can have negative hydrologic impacts (Miller et al., 2005; Petersen and Stringham, 2008; Pierson et al., 2007; Petersen et al., 2009; Pierson et al., 2010; Williams et al., 2014a, 2018). Encroaching trees outcompete understory sagebrush and herbaceous vegetation over time and thereby increase bare ground and connectivity of runoff and sediment sources (Bates et al., 2000; Miller et al., 2000; Bates et al., 2005; Petersen et al., 2009; Pierson et al., 2010; Roundy et al., 2017). Extensive well-connected bare patches in the later stages of woodland encroachment propagate broad-scale runoff generation and soil loss during storms events. Runoff from splash-sheet processes during these events combine along hillslopes to form concentrated overland flow with high sediment detachment rates and ample transport capacity (Pierson et al., 2010; Williams et al., 2014a,

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2016a). Amplified soil loss over time perpetuates a woodland ecological state and long-term site degradation (Petersen et al., 2009). Land managers commonly employ various mechanical treatments and prescribed and natural fires to reduce tree cover and re-establish sagebrush vegetation and associated resource-conserving hydrologic function (Bates et al., 2000, 2005; Pierson et al., 2007; Bates et al., 2014; Miller et al., 2014; Roundy et al., 2014; Bates et al., 2017; Williams et al., 2018). However, managers are challenged with predicting potential vegetation and ecohydrologic effects of tree removal across diverse woodland landscapes and with determining the appropriate type and timing of available treatment options. Invasions of fire-prone cheatgrass following prescribed and natural fires are particularly problematic. This annual grass commonly invades open patches on woodlands at lower elevations or on warmer sites, subsequently increases wildfire frequency, and potentially promotes long-term loss of surface soil and nutrients associated with recurrent burning and fire-induced runoff events (Pierson et al., 2011; Wilcox et al., 2012; Williams et al., 2014a).

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Land managers around the World need improved understanding of runoff and erosion processes for the various disturbances common to rangelands and need improved tools for predicting responses to and making decisions on a host of management alternatives. Managers rely on local understanding and conceptual and quantitative science-based models to aid management decisions. Local knowledge is often limited and data necessary to populate conceptual and science-based models are likewise limited given vast rangeland domain. Vegetation and ground cover inventories and field-based experiments are primary resources for informing conceptual models (Petersen et al., 2009; Chambers et al., 2014; Williams et al., 2016a; Chambers et al., 2017). Rainfall simulation and overland flow experiments likewise provide data for developing, evaluating, and enhancing quantitative hydrology and erosion predictive technologies (Flanagan and Nearing, 1995; Robichaud et al., 2007; Wei et al., 2009; Nearing et al., 2011; Al-Hamdan et al., 2012a, 2012b, 2013, 2015, 2017; Hernandez et al., 2017). To this need, we present an ecohydrologic dataset containing 1021 experimental plots. The dataset consists of rainfall simulation (1300 plot runs, 0.5 m^2 to 13 m^2 scales) and overland flow (838 plot runs, ~9 m^2 scale) experimental data with paired measures of vegetation and ground cover, and surface soil physical properties spanning point to hillslope scales (Pierson et al., 2019). The experimental data were collected at multiple sagebrush rangelands in the Great Basin, USA, each with woodland encroachment and sampled in untreated conditions and following fire and mechanical tree-removal treatments over a 10 yr period. The dataset therefore represents diverse vegetation, ground cover, and surface soil conditions common to undisturbed and disturbed rangelands in the western US and elsewhere. The resulting dataset contributes to both process-based knowledge and provision of data for populating, evaluating, and improving conceptual and quantitative hydrology and erosion models.

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2 Study Sites and Experimental Design

A series of vegetation, soils, rainfall simulation (Figures 1 and 2a-2c), and overland flow experiments (Figure 2d-2e) were completed at three pinyon and juniper woodlands historically vegetated as sagebrush shrublands. The study sites were selected from a network of sites as part of a larger study on the ecological impacts of invasive species and woodland encroachment into sagebrush ecosystems and the effects of sagebrush restoration practices, the Sagebrush Steppe Treatment Evaluation Project (SageSTEP, www.sagestep.org). Study site climate, physical, and vegetation attributes are provided in Table 1. All data were collected in summer months in years 2006-2015, with sampling years varying by site and by treatment area within each site (see Table 2). Vegetation and ground cover were patchy and sparse at the sites when the study began in 2006 (Table 1). Tree-removal treatments (prescribed fire, tree cutting, tree shredding [bullhog]) were applied at the Marking Corral and Onaqui sites in 2006 (late summer and autumn) to evaluate effectiveness of pinyon and juniper removal in re-establishing sagebrush vegetation and ground cover, improving hydrologic function, and reducing erosion rates. The Castlehead site burned by wildfire in summer 2007 before tree-removal treatments could be applied, and, wildfire was assessed as a prescribed natural-fire tree-removal treatment for that site. At all three sites, a cut-tree (downed tree) treatment was placed across a subset of large-rainfall and overland-flow plot bases (Figure 2e) within the various treatments to measure effects of downed trees on surface hydrology and erosion processes. This additional treatment was applied in 2007 and 2015 to some plots in cut treatment areas at Marking Corral and Onaqui and in 2008 and 2009 in unburned areas at Castlehead. Treatment applications and descriptions and the study experimental design are explained in earlier papers by Pierson et al. (2010, 2013, 2014, 2015) and by Williams et al. (2014a, 2019a, 2020) and all treatments for each site each year are provided in Table 2.

A suite of biological and physical attributes at each site were measured at point, small-rainfall plot (0.5 m^2), overland-flow plot (~9 m^2), large-rainfall plot (13 m^2), and hillslope plot (990 m^2) scales. Soil bulk density of the near-surface (0-5 cm depth) was sampled as a point measure in interspace microsites between plants, shrub coppice microsites underneath shrub canopies, and tree coppice microsites underneath three canopies. The bulk density sampling was conducted by compliant cavity method within all treatment areas 1-2 yr after respective treatments. Surface soil texture was quantified as a point measure using grab samples (0-2 cm depth) from interspace, shrub coppice, and tree coppice microsites within all treatment areas at Marking and Onaqui in 2006 prior to treatments and within unburned and burned treatment areas at Castlehead in 2008. Vegetation and ground cover were measured at small-rainfall, large-rainfall, and overland-flow plot scales and at the hillslope scale pre- and post-treatment in all treatment areas at Marking Corral and Onaqui and in unburned and burned treatment areas at Castlehead. Vegetation and ground cover measures on rainfall simulation and overland flow plots were used to evaluate resisting and driving forces on surface hydrology and erosion processes and to quantify treatment effects on cover components at those plot scales. Sampling of vegetation and ground cover on rainfall simulation and overland flow plots in untreated areas (control and unburned) and treated areas varied by site and year as described in Table 2. Vegetation and ground cover measures at the hillslope scale (site characterization plots) were conducted to describe site-level cover conditions prior to and over time after treatment. Site characterization plots were installed and sampled prior to treatment (2006) in all treatment areas at Marking Corral and Onaqui and were re-sampled 1 yr (2007) and 9 yr (2015) after treatment. Castlehead site characterization plots were installed and sampled in unburned and burned areas 1 yr after the fire (2008) and were re-sampled the 2nd year post-fire (2009).

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Rainfall simulations and overland flow experiments were employed at the different plot scales to quantify specific scale-dependent runoff and erosion processes (Pierson et al., 2010; Williams et al., 2014a). Small-plot rainfall simulations (Figure 1) were applied to quantify runoff and erosion by splash-sheet processes. Each small rainfall plot was installed, as described by Pierson et al. (2010) and Williams et al. (2014a), to occur on either a tree coppice, shrub coppice, or interspace microsite (Figure 1b-1e). Small plots at Marking Corral and Onaqui were installed and sampled in control and all other treatment areas in 2006 before application of the tree-removal treatments and were left in place for subsequent sampling 1 yr (2007), 2 yr (2008), and 9 yr (2015) after treatment. Small plots at Castlehead were installed and sampled in unburned and burned areas 1 yr after the fire (2008) and left in place for subsequent sampling the 2nd year after fire (2009). Large-plot rainfall simulations (Figure 2a-2b) were used to quantify runoff and erosion from combined splash-sheet and concentrated overland flow processes. Each plot was installed, as described by Pierson et al. (2010) and Williams et al. (2014a), on either a tree zone (tree coppice and area just outside tree canopy drip line) or a shrub-interspace zone (intercanopy area between tree canopies) inclusive of shrub coppice and interspace microsites (Figure 2). Large plots at Marking Corral and Onaqui were installed and sampled in all treatment areas in 2006 immediately before treatment application (controls) and were extracted following sampling. New plots were installed and sampled in treatment areas at Marking Corral and Onaqui in 2007, 1 yr post-treatment, and were then extracted. Large rainfall plots at Castlehead were installed and sampled in unburned and burned areas in 2008, 1 yr after the fire, and were then extracted. Overland flow simulations (Figure 2d-de) were conducted on large rainfall plots (Figure 2a-2c) at Marking Corral and Onaqui in 2006 and 2007 immediately following respective rainfall simulations. Overland flow simulations were conducted in control and treated areas at those sites in 2008, but those plots were not subjected to rainfall simulation. Castlehead overland flow simulations in 2008, 1 yr post-fire, were run on large rainfall simulation plots following rainfall simulations and, in 2009, 2 yr post-fire, were run on newly installed plots without rainfall simulations. Overland flow experiments conducted on large-rainfall simulation plots had borders on all sides and contained a collection trough for runoff measurement at the plot base (Figure 2c; Pierson et al., 2010, 2013, 2015; Williams et al., 2014a). Overland flow simulations run independent of rainfall-simulation experiments were conducted on borderless plots, but contained a runoff collection trough at the downslope plot base (Figure 2d-2e; Pierson et al., 2013, 2015; Williams et al., 2014a, 2019a, 2020).

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3 Field Methods

3.1 Hillslope scale site characterization plots

Understory vegetation and ground cover and overstory tree cover at the hillslope scale at each site were sampled on 30 m × 33 m site characterization plots using a suite of line-point and belt transect methods and various tree measures (see Pierson et al., 2010; Williams et al., 2014a). Foliar and ground cover on each site characterization plot were recorded for 60 points (50 cm spacing) along each of five line-point transects (30 m in length; spaced 5-8 m apart) for a total of 300 sample points per plot. Percent cover by each sampled cover type was derived for each plot as the number of respective cover type hits divided by the total number of points sampled. Multiple canopy layers were possible and therefore the total foliar cover across all sampled cover types potentially exceeded 100%. The number of live tree seedlings 5-50 cm height and shrubs exceeding 5-cm height were quantified along three belt transects on each plot. Each of the three belt transects on each plot were centered along a foliar/ground cover line-point transect, sized 2 m wide × 30 m long, and spaced 6 m apart. Shrub and tree seedling densities were calculated for each plot as the total number of respective individuals tallied along the three belt transects divided by total belt transect area (180 m^2). The number of live trees > 0.5 m in height was quantified for each plot, and tree height and minimum and maximum crown diameters were measured for each live tree. A crown radius for each live tree was derived as one-half the average of measured minimum and maximum crown diameters. Individual tree crown area (tree cover) was calculated as equivalent to the area of a circle, derived with the respective crown radius. Total tree cover for each plot was quantified as the sum of measured tree cover values on the plot.

3.2 Small-rainfall simulation plots and experiments

Foliar cover, ground cover, and ground surface roughness on all small-rainfall plots were quantified using point frame methods explained in Pierson et al. (2010). Foliar and ground cover on each plot were sampled at 15 points spaced 5 cm apart along each of seven transects spaced 10 cm apart and oriented parallel to hillslope contour (105 sample points per plot). Percent cover for each cover type sampled on each plot was derived from the frequency of respective cover type hits divided by the total number of points sampled. Multiple canopy layers were allowed and therefore total foliar cover across all cover types potentially exceeded 100%. A relative ground surface height at each sample point on each plot was determined by metal ruler as the distance between the ground surface and a level-line (top of point frame). Ground surface roughness for each plot was then derived as the mean of standard deviations of ground surface heights for each of the transects sampled on the respective plot. Litter depth on each plot was measured along the outside edge of the two plot borders located perpendicular to the hillslope contour. Measurements were made to the nearest 1 mm using a metal ruler at four evenly spaced points (15-cm apart) along the two plot borders. An average litter depth was derived for each plot as the average of the eight litter depth measures.

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Soil water repellency of the mineral soil surface and at depths near the mineral soil surface (0-5 cm depths) was measured immediately adjacent (~ 50 cm away) to each small-rainfall plot immediately before rainfall simulation using the water drop penetration time (WDPT) method (see Pierson et al., 2010). Litter and ash cover were carefully removed from the mineral soil surface prior to application of the WDPT. Eight water drops (~ 3-cm spacing) were then placed on the mineral soil surface and the time required for infiltration of each drop was recorded up to a 300-s maximum. The WDPT was then repeated at 1-cm soil depth increments until 5-cm soil depth was reached. For each sampled depth, 1 cm of soil was excavated immediately underneath the previously sampled area and the WDPT procedure was repeated with eight drops. A mean WDPT for each sampled soil depth on each plot was recorded as the average of the eight WDPT (s) samples at the respective depth. Soils were classified as wettable where mean WDPT < 5 s, slightly water repellent where mean WDPT ranged 5 s to 60 s, and strongly water repellent where mean WDPT > 60 s.

Surface soil moisture and aggregate stability were also sampled for each small-rainfall plot prior to rainfall simulations. Soil samples were collected at 0-5 cm depth immediately adjacent to each small rainfall plot and were subsequently analyzed in the laboratory for gravimetric soil water content. Some samples were excluded from the dataset due to poor sealing of soil cans in the field. Aggregate stability of the surface soil on each plot was determined using a modified sieve test on six soil peds approximately 2-3 mm thick and 6-8 mm in diameter (see Pierson et al., 2010). Each soil ped sampled on each plot was assigned to one of the following classes, as defined by Herrick et al. (2005): (1) > 10% stable aggregates, 50% structural integrity lost within 5 s, (2) > 10% stable aggregates, 50% structural integrity lost within 5-30 s, (3) > 10% stable aggregates, 50% structural integrity lost within 30-300 s, (4) 10-25% stable aggregates, (5) 25-75% stable aggregates, or (6) 75-100% stable aggregates. An average aggregate stability was derived for each plot as the arithmetic average of the classes assigned to the six aggregate samples for the respective plot.

Rainfall was applied to small-rainfall plots at approximate intensities of 64 mm h^{-1} (dry run) and 102 mm h^{-1} (wet run) for 45 min as explained in Pierson et al. (2010). The dry run was applied to dry antecedent soil conditions, and the wet run was applied to wet soil conditions, ~ 30 min after the dry run. Rainfall was applied to small-rainfall plots by a Meyer and Harmon-type portable oscillating-arm rainfall simulator fitted with 80-100 Veejet nozzles (Figure 1a; Meyer and Harmon, 1979; Pierson et al. 2010, 2013, 2014; Williams et al., 2014a, 2019a, 2020). The applied rainfall kinetic energy (200 kJ ha^{-1} mm^{-1}) and raindrop size (2 mm) were within approximately 70 kJ ha^{-1} mm^{-1} and 1 mm respectively of values reported for natural convective rainfall (Meyer and Harmon, 1979). Rainfall amount applied to each plot during rainfall simulation was estimated by integrating a pan catch of a 5-min calibration run prior to each rainfall simulation plot run. Total rainfall amount was estimated on plots where debris and/or vegetation prevented placement of calibration pans. In such cases, the estimated rainfall amount was derived as the average of all calibration runs for the respective simulation date. Timed plot runoff samples were collected at 1-3-min intervals throughout each 45-min rainfall simulation and were subsequently analyzed in the laboratory for runoff volume and sediment concentration. Cumulative runoff and sediment amounts were obtained for each runoff sample by weighing the sample before and after drying at 105°C (Pierson et al., 2010). Runoff samples were not filtered at any stage of laboratory processing. A mean runoff rate (mm h^{-1} and L min^{-1}) was derived for each sample interval as the interval runoff divided by the interval time. Sediment discharge (g s^{-1}) for each sample interval was calculated as the cumulative sediment for the sample interval divided by the interval time. Sediment concentration for each sample interval was obtained by dividing cumulative sediment by cumulative runoff (g L^{-1}). Some field samples were discarded from the final dataset because of laboratory errors or various issues noted on field datasheets (i.e., spillage, bottle overrun, etc.).

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3.3 Large-rainfall simulation plots and experiments

Vegetation and ground cover were measured on large-rainfall simulation plots using line-point methods as described by Pierson et al. (2010) and Williams et al. (2014a). Foliar cover and ground cover on large-rainfall plots were recorded for 59 points with 10-cm spacing along each of five transects (6 m long, spaced 40 cm apart) oriented perpendicular to the hillslope contour, 295 sample points per plot. The percentage cover by each sampled cover type for each plot was derived as the number of point contacts or hits for each respective life form divided by the total number of points sampled on the respective plot. Multiple canopy layers were allowed and therefore total foliar cover across all sampled cover types potentially exceeded 100%. Cut trees placed on a subset of rainfall simulation plots (see experimental design above) were excluded from foliar and ground cover measurements. However, various attributes of downed trees (i.e., length [height], crown width, etc.) were measured and are reported. Ground surface roughness for each plot was calculated as the average of the standard deviations of ground surface heights measured across the line-point cover transects. The relative ground-surface height at each sample point was calculated as the distance between a survey transit level-line above the point and the ground surface. Distances in excess of 20 cm between plant canopies (canopy gaps) and plant bases (basal gaps) were measured along each of the line-point transects on each plot. Average canopy and basal gap sizes were calculated for each plot as the mean of all respective gaps measured in excess of 20 cm. Additionally, maximum canopy and basal gap sizes were calculated for each plot as the maximum of all respective gaps measured in excess of 20 cm. Percentages of canopy gaps and basal gaps representing 50-cm incremental gap classes (e.g., 51-100 cm, 101-150 cm, etc.) were derived for each transect and averaged across the transects on each plot to determine gap-class plot means.

Rainfall was applied to pairs of large-rainfall plots (Figure 2a-2b) at the same dry-run and wet-run target rates and sequence and durations as described above for small-rainfall plots (Pierson et al., 2010; Williams et al., 2014a). Each paired-rainfall simulation was run with a Colorado State University (CSU) type rainfall simulator (Figure 2a-2b; Holland, 1969). The CSU-type design delivers rainfall energy at approximately 70% of that for a natural convective rainfall event and produces rainfall drop diameters within approximately 1 mm of natural rainfall (Holland, 1969; Neff, 1979). The applied simulator design consists of seven stationary sprinklers evenly spaced along each of the outermost borders of the respective rainfall-plot pair, with each sprinkler elevated 3.05 m above the ground surface. Total rainfall applied to large-rainfall plots was quantified from the average of six plastic rainfall depth gages organized in a uniform grid within each plot. Runoff from direct rainfall on the large-plot collection troughs (trough catch, Figure 2b) was quantified by sampling collection trough runoff before plot-generated runoff occurred. Once plot runoff occurred, timed samples of runoff were collected at 1-3-min intervals throughout each 45-min simulation run and were subsequently analyzed in the laboratory for runoff volume and sediment concentration as with small-plot rainfall simulation runoff samples. Sample weights were adjusted to appropriately account for trough catch, as described by Pierson et al. (2010). Some field samples were discarded from the final dataset because of laboratory errors or various issues noted on field datasheets (i.e., spillage, bottle overrun, etc.). Runoff and erosion rates were determined consistent with methods for small-plot rainfall simulations.

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3.4 Overland-flow simulation plots and experiments

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Vegetation and ground cover on overland-flow plots were measured using methods consistent with those on large-rainfall simulation plots. For overland-flow plots that underwent rainfall simulation, foliar and ground cover measures were derived from the large-rainfall plot line-point transect data, but were restricted to the lower 4 m of the respective plots. Foliar and ground cover on overland-flow plots not subjected to rainfall simulations were recorded at 24 points with 20-cm spacing, along each of nine line-point transects (4.6 m in length, spaced 20 cm apart) oriented perpendicular to the hillslope contour, for a total of 216 points per plot. Percentage cover for each cover type sampled on each plot was derived from the number of point contacts or hits for each respective cover type divided by the total number of points sampled within the plot. As on large-rainfall plots, total foliar cover across all cover types potentially exceeded 100% given multiple canopy layers were allowed. Cut trees placed on a subset of overland-flow plots (see experimental design above) were excluded from foliar and ground cover measurements. However, various attributes of downed trees (i.e., length [height], crown width, etc.) were measured and are reported. The ground surface roughness for each overland-flow plot was calculated as the average of the standard deviations of the ground surface heights across the foliar/ground cover line-point transects. The relative ground-surface height at each cover sample point was calculated as the distance between a survey transit level line above the respective sample point and the ground surface. Canopy and basal gaps exceeding 20 cm on overland-flow plots were recorded along each line-point transect. Average and maximum canopy and basal gaps were derived consistent with methods for large-rainfall simulation plots. Percentages of canopy and basal gaps representing 50-cm incremental gap classes (e.g., 51-100 cm, 101-150 cm, etc.) were derived for each transect and averaged across the transects on each plot to determine gap-class plot means, similar as on large-rainfall plots.

Datalogger-controlled flow regulators (see Pierson et al., 2010, 2013, 2015; Williams et al., 2014a, 2019a, 2020) were used to apply concentrated flow release rates of 15, 30, and 45 L min^{-1} to each overland-flow plot. Flow was routed into and through a metal box filled with Styrofoam pellets and was released through a 10-cm wide mesh-screened opening at the box base (Figure 2d; see Pierson et al., 2010). Each flow release on each plot was applied for 12 min from a single release-point located 4 m upslope of the collection trough apex. Flow release rate progression on each plot was consecutive from 15 L min^{-1} to 30 L min^{-1} to 45 L min^{-1}. Flow samples were collected at various time intervals (usually 1-min to 2-min) for each 12-min simulation at each release rate. As with rainfall simulation samples, runoff samples were taken to the laboratory, weighed, oven-dried at 105°C, and then re-weighed to determine the runoff rate and sediment concentration. Also as noted above for rainfall simulation runoff samples, a small number of runoff samples were discarded because of laboratory errors or various issues noted on field datasheets (i.e., spillage, bottle overrun, etc.). Runoff and sediment variables for each flow release rate were calculated for an 8-min time period starting at runoff initiation. The resulting 8-min runoff and sediment variables were derived as explained for the 45-min rainfall simulations. The velocity of overland flow was measured using a concentrated salt tracer applied into the flow and electrical conductivity probes to track the mean transit time of the tracer over a set flow path length (usually 3 m; Pierson et al., 2010, 2013, 2015; Williams et al., 2014a, 2019a, 2020).

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The width, depth, and a total rill area width (TRAW) of overland flow were measured along flow cross-sections 1 m, 2 m, and 3 m downslope from the flow release point (Pierson et al., 2010). The TRAW variable represents the total width between the outermost edges of the outermost flow paths at the respective cross section (see Pierson et al., 2008). Overland flow simulations conducted on large-rainfall simulation plots at Marking Corral and Onaqui in 2006 and 2007 and at Castlehead in 2008 were run approximately two hours after respective rainfall simulations. Overland flow simulations on plots not subjected to rainfall simulation at Marking Corral and Onaqui in 2008 and 2015 and at Castlehead in 2008 were conducted on soils pre-wet with a gently misting sprinkler (see Pierson et al., 2013, 2015; Williams et al., 2014, 2019a, 2020).

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4 Data Application

Subsets of the dataset have been used to improve understanding of rangeland hydrologic and erosion processes, assess the ecohydrologic impacts of wildland fire and management practices on sagebrush rangelands, and improve and enhance rangeland hydrology and erosion models. Examples of data use for such applications are presented in Figures 3-5. Pierson et al. (2010) applied pre-treatment data across all plot-scales and experiment types from Marking Corral and Onaqui to evaluate the ecohydrologic impacts of woodland encroachment on sagebrush rangelands. Studies by Pierson et al. (2014, 2015) assessed the initial (1st and 2nd year) effects of prescribed fire and mechanical tree removal treatments on vegetation, ground cover, and hydrology and erosion processes at Marking Corral and Onaqui. Williams et al. (2014a) applied vegetation, ground cover, rainfall simulation and overland flow experiments from unburned and burned areas at Castlehead to evaluate the utility of fire to reverse the negative ecohydrologic impacts of juniper encroachment on rangelands and to frame conceptual concepts on process connectivity for burned and degraded rangelands (Figure 4). Pierson et al. (2013 and 2015) evaluated the immediate effects of cut-downed trees on runoff and erosion processes on woodlands. Williams et al. (2019a, 2019b, 2020) applied data from all experimental plot scales and methods in untreated and treated areas at Marking Corral and Onaqui to evaluate the long-term ecohydrologic impacts of prescribed fire and mechanical tree-removal treatments on woodland-encroached sagebrush steppe (Figure 5). Al-Hamdan et al. (2012a, 2012b, 2013, 2015, 2017) applied subsets of the data to develop, test, and enhance various parameter estimation equations for flow hydraulics and erodibility parameters in the Rangeland Hydrology and Erosion Model (RHEM). Collectively, these studies have improved understanding of rangeland hydrology and erosion processes and informed both conceptual and quantitative models applicable to assessment and management of diverse rangelands (McIver et al., 2014; Pierson and Williams, 2016; Williams et al., 2016a, 2016b, 2016c; Hernandez et al., 2017; Williams et al., 2018).

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5 Data Availability

The full dataset is available from the US Department of Agriculture, National Agricultural Library website at https://data.nal.usda.gov/search/type/dataset (DOI: https://doi.org/10.15482/USDA.ADC/1504518; Pierson et al., 2019). The suite of files therein includes an abbreviated description and field methods; a data dictionary; geographic information for study sites; photographs of the study sites, field experiments, and experimental plots; and datafiles for vegetation, ground cover, soils, and hydrology and erosion time series measures spanning the associated plots scales. Subset examples of the datafiles are shown in Tables 4 (site level soil particle size and bulk density), 5 (site characterization plots), 6 (small-rainfall plot attributes), 7 (large-rainfall plot attributes), 8 (overland-flow plot attributes), 9 (small-plot rainfall simulation time series), 10 (large-plot rainfall simulation time series), and 11 (overland-flow simulation time series). Time series runoff and sediment data provided for rainfall simulations and overland flow experiments do not account for carryover effects from one plot run to the next on a given plot in a given year (i.e., dry-run effects on wet-run simulations; effects of 15 L min^{-1} overland flow releases on subsequent 30-45 L min^{-1} overland flow releases). Data users should consider whether carryover effects impact respective applications and make applicable adjustments to acquired data.

6 Summary and Conclusions

Rangelands are uniquely managed using ecological principles. As such, our functional understanding of regulating ecohydrologic processes, such as soil conservation and runoff moderation, are limited by our ability to track these processes in the context of interdependent land management decisions. Pinyon-juniper encroachment into sagebrush shrublands and the resulting management actions provide a model system for observing hydrologic processes under disturbances and interventions typical of extensively managed rangelands. To provide detailed understanding of ecohydrologic processes under realistic management conditions, we collected long-term data at multiple sites, spatial scales, and treatments. The combined dataset includes 1021 experimental plots and contains vegetation, ground cover, soils, hydrology, and erosion data spanning multiple spatial scales and diverse vegetation, ground cover, and surface soil conditions from three study sites and five different study years. The dataset includes 57 hillslope scale vegetation plots (site characterization plots), 528 small rainfall simulation plots, 146 large rainfall simulation plots, and 290 overland-flow simulation plots. The hydrology and erosion experiments provide time series data for small-rainfall plot, large-rainfall plot, and overland-flow plot simulations. After excluding some time series rainfall- and overland-flow simulation data due to various lab and equipment failures, the final time series dataset contains 1020 small-rainfall, 280 large-rainfall, and 838 overland-flow plot-run hydrographs and sedigraphs if plots without runoff are retained. Retaining only plots that generated runoff results in a time series dataset of 749 small-rainfall, 251 large-rainfall, and 719 overland-flow plot simulation hydrographs and sedigraphs. Overall, the hydrology and erosion time series dataset totals to 2138 hydrographs/sedigraphs including plots with no runoff and 1719 hydrographs/sedigraphs for plots that generated runoff. The methodology employed and resulting experimental data improve understanding of and provide quantification of separate scale-dependent (e.g., rainsplash and sheetflow) and combined (e.g., interrill and concentrated flow/rill) surface hydrology and erosion processes for sagebrush rangelands and pinyon and juniper woodlands in the Great Basin before and after tree removal and for sparsely vegetated sites elsewhere. This separate and combined experimental approach yields a valuable data source for testing and improving isolated process

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parameterizations in quantitative hydrology and erosion models. The long-term nature of the dataset is unique and provides a substantial database for populating conceptual ecological models of changes in vegetation, ground cover conditions, and surface soils resulting from management practices and disturbances. Likewise, the combined data on short-term and long-term ecohydrologic impacts of management practices and fire provide valuable insight on trends in ecohydrologic recovery of rangeland ecosystems.

Author contributions. Frederick B. Pierson, C. Jason Williams, Patrick R. Kormos, and Osama Z. Al-Hamdan participated in the experimental design, data collection and reduction, and compilation of the dataset and manuscript. Justin C. Johnson contributed to data reduction and compilation of the dataset and manuscript. All authors contributed to revisions of the submitted manuscript.

Competing interests. The authors declare that they have no conflict of interest.

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References

Al-Hamdan, O. Z., Pierson, F. B., Nearing, M. A., Stone, J. J., Williams, C. J., Moffet, C. A., Kormos, P. R., Boll, J., and Weltz, M. A.: Characteristics of concentrated flow hydraulics for rangeland ecosystems: Implications for hydrologic modeling, Earth Surface Processes and Landforms, 37, 157-168, 2012a.

Al-Hamdan, O. Z., Pierson, F. B., Nearing, M. A., Williams, C. J., Stone, J. J., Kormos, P. R., Boll, J., and Weltz, M. A.: Concentrated flow erodibility for physically based erosion models: Temporal variability in disturbed and undisturbed rangelands, Water Resources Research, 48, W07504, 2012b.

Al-Hamdan, O. Z., Pierson, F. B., Nearing, M. A., Williams, C. J., Stone, J. J., Kormos, P. R., Boll, J., and Weltz, M. A.: Risk assessment of erosion from concentrated flow on rangelands using overland flow distribution and shear stress partitioning, Transactions of the ASABE, 56, 539-548, 2013.

Al-Hamdan, O. Z., Hernandez, M., Pierson, F. B., Nearing, M. A., Williams, C. J., Stone, J. J., Boll, J., and Weltz, M. A.: Rangeland Hydrology and Erosion Model (RHEM) enhancements for applications on disturbed rangelands, Hydrological Processes, 29, 445-457, 2015.

Al-Hamdan, O. Z., Pierson, F. B., Nearing, M. A., Williams, C. J., Hernandez, H., Boll, J., Nouwakpo, S. K., Weltz, M. A., and Spaeth, K. E.: Developing a Parameterization Approach for Soil Erodibility for the Rangeland Hydrology and Erosion Model (RHEM), Transactions of the American Society of Agricultural and Biological Engineers, 60, 85-94, 2017.

Bates, J. D., Miller, R. F., and Svejcar, T. J.: Understory dynamics in cut and uncut western juniper woodlands, Journal of Range Management, 53, 119-126, 2000.

Bates, J. D., Miller, R. F., and Svejcar, T.: Long-term successional trends following western juniper cutting, Rangeland Ecology and Management, 58, 533-541, 2005.

Bates, J. D., Sharp, R. N., and Davies, K. W.: Sagebrush steppe recovery after fire varies by development phase of Juniperus occidentalis woodland, International Journal of Wildland Fire, 23, 117-130, 2014.

Bates, J. D., Svejcar, T., Miller, R., and Davies, K. W.: Plant community dynamics 25 years after juniper control, Rangeland Ecology and Management, 70, 356-362, 2017.

Chambers, J. C., Miller, R. F., Board, D. I., Pyke, D. A., Roundy, B. A., Grace, J. B., Schupp, E. W., and Tausch, R. J.: Resilience and resistance of sagebrush ecosystems: implications for state and transition models and management treatments, Rangeland Ecology and Management, 67, 440-454, 2014.

Chambers, J. C., Maestas, J. D., Pyke, D. A., Boyd, C. S., Pellant, M., and Wuenschel, A.: Using resilience and resistance concepts to manage persistent threats to sagebrush ecosystems and greater sage-grouse, Rangeland Ecology and Management, 70, 149-164, 2017.

Davies, K. W., Boyd, C. S., Beck, J. L., Bates, J. D., Svejcar, T. J., and Gregg, M. A.: Saving the sagebrush sea: An ecosystem conservation plan for big sagebrush plant communities, Biological Conservation, 144, 2573-2584, 2011.

Emmett, W. W.: The hydraulics of overland flow on hillslopes, US Government Printing Office, Washington, D.C., 69 pp., 1970.

Flanagan, D. C., and Nearing, M. A. USDA-Water Erosion Prediction Project (WEPP) hillslope profile and watershed model documentation, NSERL Report No. 10, National Soil Erosion Research Laboratory, USDA-Agricultural Research Service, West Lafayette, IN, USA, 298 pp., 1995.

Havstad, K. M., Peters, D. C., Allen-Diaz, B., Bartolome, J., Betelmeyer, B. T., Briske, D., Brown, J., Brunsun, M., Herrick, J. E., Huntsinger, L., Johnson, P., Joyce, L., Pieper, R., Svejcar, A. J., and Yao, J.: The western United Sates rangelands, a major resource, in: Grassland: Quietness and Strength for a New American Agriculture, edited by: Wedin,W. F., and Fales, S. L., American Society of Agronomy Inc., Crop Science Society of America Inc., and Soil Science Society of America, Inc., Madison, WI, USA, 75-93, 2009.

Hernandez, M., Nearing, M. A., Al-Hamdan, O. Z., Pierson, F. B., Armendariz, G., Weltz, M. A., Spaeth, K. E., Williams, C. J., Nouwakpo, S. J., Goodrich, D. C., Unkrich, C.L., Nichols,

M. H., and Holifield Collins, C. D.: The rangeland hydrology and erosion model: A dynamic approach for predicting soil loss on rangelands, Water Resources Research, 53, 9368-9391, https://doi.org/10.1002/2017WR020651, 2017.

Herrick, J. E., Van Zee, J. W., Havstad, K. M., Burkett, L. M., and Whitford, W. G.: Monitoring manual for grassland, shrubland, and savanna ecosystems, Volume 1: Quick Start, USDA-Agricutural Research Service, Las Cruces, NM, USA, 36 pp., 2005.

Ludwig, J. A., Wilcox, B. P., Breshears, D. D., Tongway, D. J., and Imeson, A. C.: Vegetation patches and runoff-erosion as interacting ecohydrological processes in semiarid landscapes, Ecology, 86, 288-297, 2005.

McIver, J., Brunson, M., Bunting, S., Chambers, J., Doescher, P., Grace, J., Hulet, A., Johnson, D., Knick, S., Miller, R., Pellant, M., Pierson, F., Pyke, D., Rau, B., Rollins, K., Roundy, B., Schupp, E., Tausch, R., and Williams, J.: A synopsis of short-term response to alternative restoration treatments in sagebrush-steppe: The SageSTEP Project, Rangeland Ecology and Management, 67, 584-598, 2014.

Miller, R. F., Bates, J. D., Svejcar, T. J., Pierson, F. B., and Eddleman, L. E.: Biology, ecology, and management of western juniper, Oregon State University Agricultural Experiment Station Technical Bulletin 152, Oregon State University, Oregon State University Agricultural Experiment Station, Corvallis, OR, USA, 82 pp., 2005.

Miller, R. F. Chambers, J. C., Evers, L., Williams, C. J., Snyder, K. A., Roundy, B. A., and Pierson, F. B. The ecology, history, ecohydrology, and management of pinyon and juniper woodlands in the Great Basin and Northern Colorado Plateau of the western United States, General Technical Report RMRS-GTR-403, US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, USA, 2019.

Miller, R. F., Knick, S. T., Pyke, D. A., Meinke, C. W., Hanser, S. E., Wisdom, M. J., and Hild, A. L.: Characteristics of sagebrush habitats and limitations to long-term conservation, in: Greater Sage-grouse: Ecology and Conservation of a Landscape Species and Its Habitats. Studies in Avian Biology, Vol. 38, edited by: Knick, S. T., and Connelly, J. W., University of California Press, Berkeley, CA, USA, 145–184, 2011.

Miller, R. F., Ratchford, J., Roundy, B. A., Tausch, R. J., Hulet, A., and Chambers, J.: Response of conifer-encroached shrublands in the Great Basin to prescribed fire and mechanical treatments, Rangeland Ecology and Management, 67, 468-481, 2014.

Miller, R. F., Svejcar, T. J., and Rose, J. A.: Impacts of western juniper on plant community composition and structure, Journal of Range Management, 53, 574-585, 2000.

NRCS (Natural Resources Conservation Service), Soil survey of Owyhee County area, Idaho, US Department of Agriculture, Natural Resources Conservation Service, Washington, DC, USA, 2003.

NRCS (Natural Resources Conservation Service), Soil Survey Geographic (SSURGO) database for Tooele Area, Utah - Tooele County and Parts of Box Elder, Davis, and Juab Counties, Utah, White Pine and Elko Counties, Nevada, US Department of Agriculture, Natural Resources Conservation Service, Fort Worth, TX, USA, 2006.

NRCS (Natural Resources Conservation Service), Soil Survey Geographic (SSURGO) database for Western White Pine County Area, Nevada, Parts of White Pine and Eureka Counties. US Department of Agriculture, Natural Resources Conservation Service, Fort Worth, TX., USA, 2007.

Deleted: B.

Deleted: , Roundy, B. A., Snyder, K., and Williams, C. J.

Deleted: History, ecology, ecohydrology, and management of pinyon and juniper woodlands in the Great Basin and Colorado Plateau

Nearing, M. A., Wei, H., Stone, J. J., Pierson, F. B., Spaeth, K. E., Weltz, M. A., Flanagan, D. C., and Hernandez, M.: A rangeland hydrology and erosion model, Transactions of the ASABE, 54, 901-908, 2011.

Petersen, S. L., and Stringham, T. K.: Infiltration, runoff, and sediment yield in response to western juniper encroachment in southeast Oregon, Rangeland Ecology and Management, 61, 74-81, 2008.

Petersen, S. L., Stringham, T. K., and Roundy, B. A.: A process-based application of state-and-transition models: A case study of western juniper (*Juniperus occidentalis*) encroachment, Rangeland Ecology and Management, 62, 186-192, 2009.

Pierson, F. B., Bates, J. D., Svejcar, T. J., and Hardegree, S. P.: Runoff and erosion after cutting western juniper, Rangeland Ecology and Management, 60, 285-292, 2007.

Pierson, F. B., Moffet, C. A., Williams, C. J., Hardegree, S. P., and Clark, P. E.: Prescribed-fire effects on rill and interrill runoff and erosion in a mountainous sagebrush landscape, Earth Surface Processes and Landforms, 34, 193-203, 2009.

Pierson, F. B., Robichaud, P. R., Moffet, C. A., Spaeth, K. E., Hardegree, S. P., Clark, P. E., and Williams, C. J.: Fire effects on rangeland hydrology and erosion in a steep sagebrush-dominated landscape, Hydrological Processes, 22, 2916-2929, 2008.

Pierson Jr, F. B., Van Vactor, S. S., Blackburn, W. H., and Wood, J. C.: Incorporating small scale spatial variability into predictions of hydrologic response on sagebrush rangelands, in: Variability in rangeland water erosion processes (Soil Science Soceity of America Special Publication 38), edited by: Blackburn, W. H., Pierson, F. B., Schuman, G. E., and Zartman, R., Soil Science Society of America, Madison, WI, USA, 23-34, 1994.

Pierson, F. B., and Williams, C. J.: Ecohydrologic impacts of rangeland fire on runoff and erosion: A literature synthesis, General Technical Report RMRS-GTR-351, US Department of Agriculture, Forest Service, 110 pp., 2016.

Pierson, F. B., Williams, C. J., Hardegree, S. P., Weltz, M. A., Stone, J. J., and Clark, P. E.: Fire, plant invasions, and erosion events on western rangelands, Rangeland Ecology and Management, 64, 439-449, 2011.

Pierson, F. B., Williams, C. J., Hardegree, S. P., Clark, P. E., Kormos, P. R., and Al-Hamdan, O. Z.: Hydrologic and erosion responses of sagebrush steppe following juniper encroachment, wildfire, and tree cutting, Rangeland Ecology and Management, 66, 274-289, https://doi.org/10.2111/REM-D-12-00104.1, 2013.

Pierson, F. B., Williams, C. J., Kormos, P. R., and Al-Hamdan, O. Z.: Short-term effects of tree removal on infiltration, runoff, and erosion in woodland-encroached sagebrush steppe, Rangeland Ecology and Management, 67, 522-538, https://doi.org/10.2111/REM-D-13-00033.1, 2014.

Pierson, F. B., Williams, C. J., Kormos, P. R., Al-Hamdan, O. Z., and Johnson, J. C.: Vegetation, rainfall simulation, and overland flow experiments before and after tree removal in woodland-encroached sagebrush steppe: the SageSTEP hydrology study. Ag Data Commons, https://doi.org/10.15482/USDA.ADC/1504518, 2019.

Pierson, F. B., Williams, C. J., Kormos, P. R., Hardegree, S. P., Clark, P. E., and Rau, B. M.: Hydrologic vulnerability of sagebrush steppe following pinyon and juniper encroachment, Rangeland Ecology and Management, 63, 614-629, https://doi.org/10.2111/REM-D-09-00148.1, 2010.

Pierson, F. B., Williams, C. J., Kormos, P. R., Al-Hamdan, O. Z., Hardegree, S. P., and Clark, P. E.: Short-term impacts of tree removal on runoff and erosion from pinyon- and juniper-dominated sagebrush hillslopes, Rangeland Ecology and Management, 68, 408-422, http://dx.doi.org/10.1016/j.rama.2015.07.004, 2015.

Prism Climate Group, 2019. Oregon State University, Prism Climate Group. Available at http://www.prism.oregonstate.edu. Accessed on 20 September 2019.

Puigdefabregas, J.: The role of vegetation patterns in structuring runoff and sediment fluxes in drylands, Earth Surface Processes and Landforms, 30, 133-147, 2005.

Reid, K. D., Wilcox, B. P., Breshears, D. D., and MacDonald, L.: Runoff and erosion in a pinon-juniper woodland: Influence of vegetation patches, Soil Science Society of America Journal, 63, 1869-1879, 1999.

Robichaud, P. R., Elliot, W. J., Pierson, F. B., Hall, D. E., and Moffet, C. A.: Predicting postfire erosion and mitigation effectiveness with a web-based probabilistic erosion model, Catena 71, 229-241, 2007.

Roundy, B. A., Young, K., Cline, N., Hulet, A., Miller, R. F., Tausch, R. J., Chambers, J. C., and Rau, B.: Piñon-juniper reduction increases soil water availability of the resource growth pool, Rangeland Ecology and Management, 67, 495-505, 2014.

Roundy, B. A., Farmer, M., Olson, J., Petersen, S., Nelson, D. R., Davis, J., and Vernon, J.: Runoff and sediment response to tree control and seeding on a high soil erosion potential site in Utah: evidence for reversal of an abiotic threshold, Ecohydrology, 10:e1775, 2017.

Schlesinger, W. H., Reynolds, J. F., Cunningham, G. L., Huenneke, L. F., Jarrell, W. M., Virginia, R. A., and Whitford, W. G.: Biological feedbacks in global desertification, Science, 247, 1043-1048, 1990.

Shakesby, R. A., and Doerr, S. H.: Wildfire as a hydrological and geomorphological agent, Earth-Science Reviews, 74, 269-307, 2006.

Shakesby, R. A.: Post-wildfire soil erosion in the Mediterranean: Review and future research directions, Earth-Science Reviews, 105, 71-100, 2011.

Wainwright, J., Parsons, A. J., and Abrahams, A. D.: Plot-scale studies of vegetation, overland flow and erosion interactions: Case studies from Arizona and New Mexico, Hydrological Processes, 14, 2921-2943, 2000.

Wei, H., Nearing, M. A., Stone, J. J., Guertin, D. P., Spaeth, K. E., Pierson, F. B., Nichols, M. H., and Moffett, C. A.: A new splash and sheet erosion equation for rangelands, Soil Science Society of America Journal, 73, 1386-1392, 2009.

Wilcox, B. P., Breshears, D. D., and Allen, C. D.: Ecohydrology of a resource-conserving semiarid woodland: Effects of scale and disturbance, Ecological Monographs, 73, 223-239, 2003.

Wilcox, B. P., Turnbull, L., Young, M. H., Williams, C. J., Ravi, S., Seyfried, M. S., Bowling, D. R., Scott, R. L., Germino, M. J., Caldwell, T. G., and Wainwright, J.: Invasion of shrublands by exotic grasses: Ecohydrological consequences in cold versus warm deserts, Ecohydrology, 5, 160-173, 2012.

Williams, C. J., Pierson, F. B., Al-Hamdan, O. Z., Kormos, P. R., Hardegree, S. P., and Clark, P. E.: Can wildfire serve as an ecohydrologic threshold-reversal mechanism on juniper-encroached shrublands, Ecohydrology, 7, 453-477, https://doi.org/10.1002/eco.1364, 2014a.

Williams, C. J., Pierson, F. B., Kormos, P. R., Al-Hamdan, O. Z., Nouwakpo, S. K., and Weltz, M. A.: Vegetation, Hydrologic, and Erosion Responses of Sagebrush Steppe 9 Years Following Mechanical Tree Removal, Rangeland Ecology and Management, 72, 47-68, https://doi.org/10.1016/j.rama.2018.07.004, 2019a.

Williams, C. J., Pierson, F. B., Nouwakpo, S. K., Al-Hamdan, O. Z., Kormos, P. R., and Weltz, M. A.: Effectiveness of prescribed fire to re-establish sagebrush steppe vegetation and ecohydrologic function on woodland-encroached sagebrush rangelands, Great Basin, USA: Part I: Vegetation, hydrology, and erosion responses, Catena, 185, 103477, https://doi.org/10.1016/j.catena.2018.02.027, 2020.

Williams, C. J., Pierson, F. B., Nouwakpo, S. K., Kormos, P. R., Al-Hamdan, O. Z., and Weltz, M. A.: Long-term evidence for fire as an ecohydrologic threshold-reversal mechanism on woodland-encroached sagebrush shrublands, Ecohydrology, 12, 2019b.

Williams, C. J., Pierson, F. B., Robichaud, P. R., Al-Hamdan, O. Z., Boll, J., and Strand, E. K.: Structural and functional connectivity as a driver of hillslope erosion following disturbance, International Journal of Wildland Fire, 25, 306-321, 2016c.

Williams, C. J., Pierson, F. B., Robichaud, P. R., and Boll, J.: Hydrologic and erosion responses to wildfire along the rangeland-xeric forest continuum in the western US: A review and model of hydrologic vulnerability, International Journal of Wildland Fire, 23, 155-172, 2014b.

Williams, C. J., Pierson, F. B., Spaeth, K. E., Brown, J. R., Al-Hamdan, O. Z., Weltz, M. A., Nearing, M. A., Herrick, J. E., Boll, J., Robichaud, P. R., Goodrich, D. C., Heilman, P., Guertin, D. P., Hernandez, M., Wei, H., Hardegree, S. P., Strand, E. K., Bates, J. D., Metz, L. J., and Nichols, M. H.: Incorporating Hydrologic Data and Ecohydrologic Relationships into Ecological Site Descriptions, Rangeland Ecology and Management, 69, 4-19, 2016a.

Williams, C. J., Pierson, F. B., Spaeth, K. E., Brown, J. R., Al-Hamdan, O. Z., Weltz, M. A., Nearing, M. A., Herrick, J. E., Boll, J., Robichaud, P. R., Goodrich, D. C., Heilman, P., Guertin, D. P., Hernandez, M., Wei, H., Polyakov, V. O., Armendariz, G., Nouwakpo, S. K., Hardegree, S. P., Clark, P. E., Strand, E. K., Bates, J. D., Metz, L. J., and Nichols, M. H.: Application of ecological site information to transformative changes on great basin sagebrush rangelands, Rangelands, 38, 379-388, 2016b.

Williams, C. J., Snyder, K. A, and Pierson, F. B.: Spatial and temporal variability of the impacts of pinyon and juniper reduction on hydrologic and erosion processes across climatic gradients in the western US: A regional synthesis, Water, 10, 1607, https://doi.org/10.3390/w10111607, 2018.

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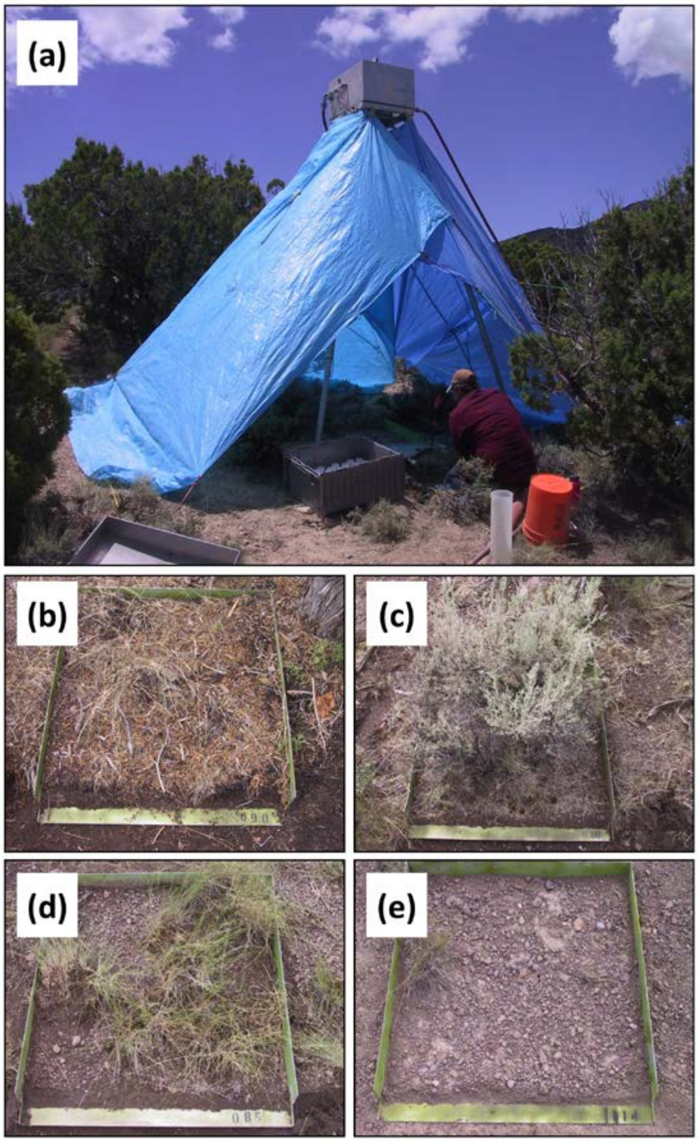

Figure 1. Photographs of small-plot rainfall simulator (**a**) and example small-rainfall plots on tree coppice (**b**), shrub coppice (c), and interspace (**d** and **e**) microsites as applied in this study.

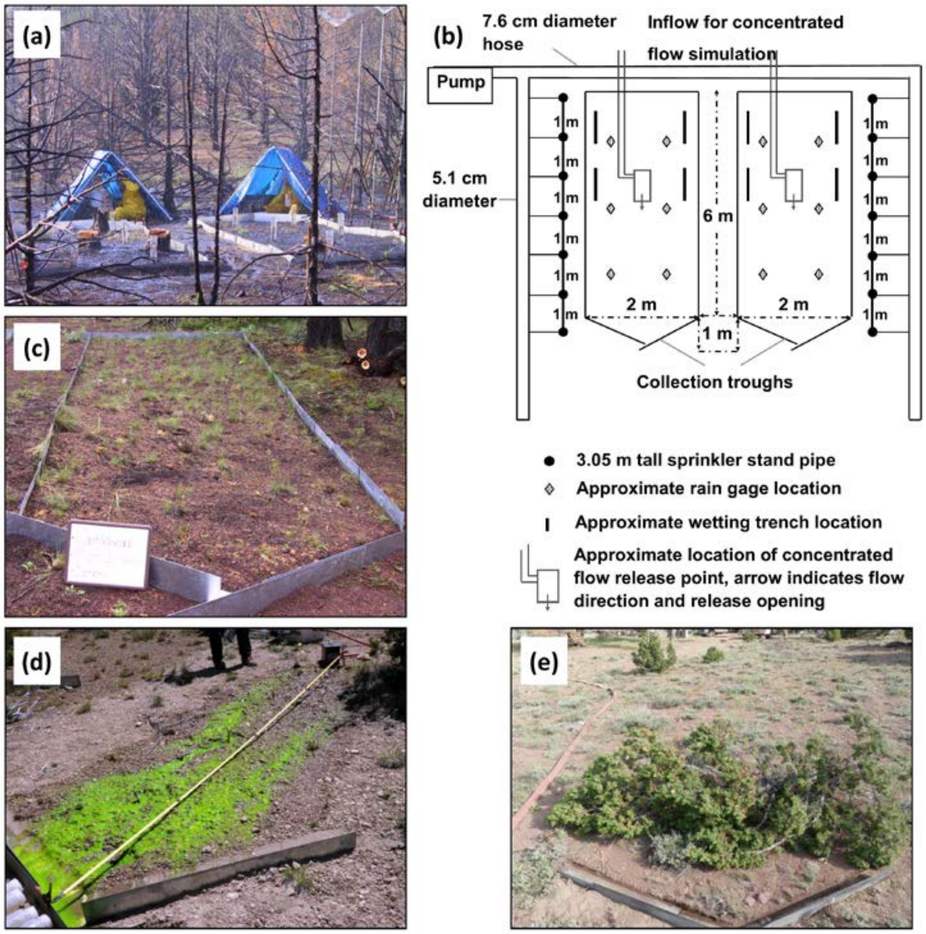

Figure 2. Images showing paired large-rainfall plots during rainfall simulations (**a**), experimental set-up of paired large-rainfall plot simulation experiments (**b**), a fully-bordered large-rainfall simulation plot on a tree coppice microsite (**c**), a borderless overland-flow simulation plot and experiment on an intercanopy (shrub-interspace) microsite (**d**), and a borderless overland-flow simulation plot with a cut, downed tree on an intercanopy microsite, all as respective examples as applied in this study.

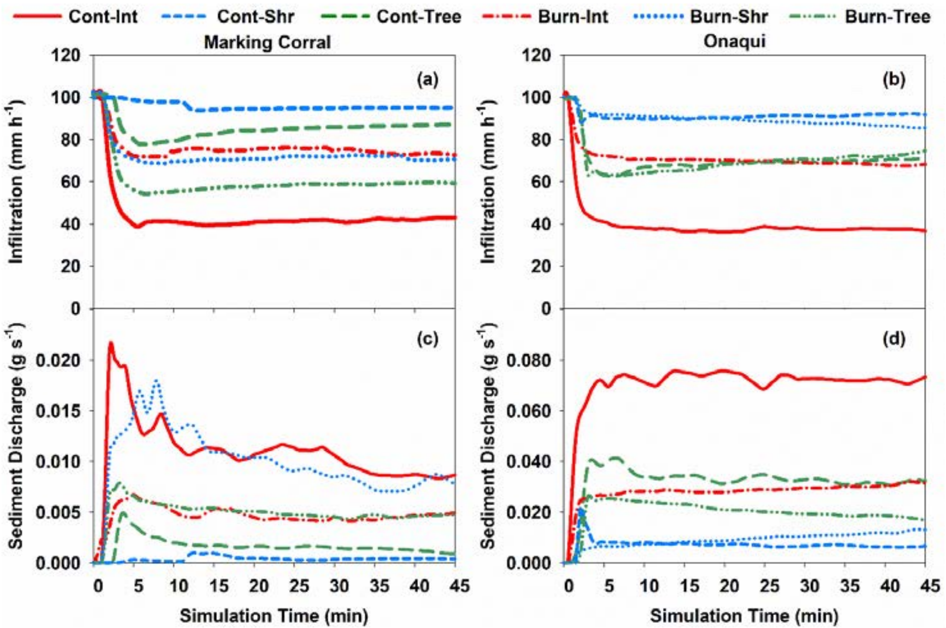

Figure 3. Example infiltration (**a** [Marking Corral] and **b** [Onaqui]), calculated as applied rainfall minus measured runoff, and sediment discharge (**c** [Marking Corral] and **d** [Onaqui]) time series data generated from a subset of the small-plot rainfall simulation dataset. Example sub-dataset is from wet-run rainfall simulations in untreated (Cont) and burned (Burn) interspace (Int), shrub coppice (Shr), and tree coppice (Tree) microsites at the Marking Corral and Onaqui study sites 9 yr following prescribed fire. The data illustrate the long-term impacts of burning and associated changes in surface conditions on infiltration and sediment discharge. Figure modified from Williams et al. (2020).

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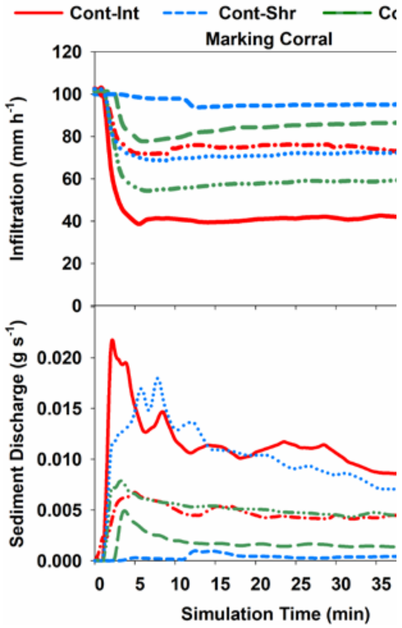

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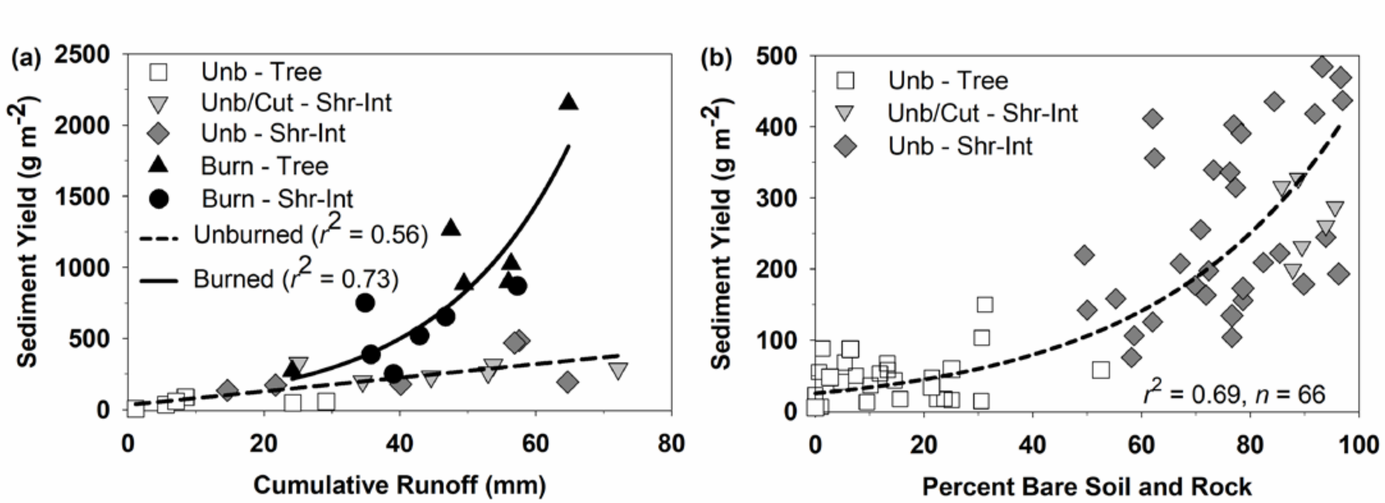

Figure 4. Example relationships/correlations in large-rainfall plot cumulative runoff and sediment yield for unburned (untreated [Unb] and cut [Cut] treatments) and burned (Burn) tree (Tree) and intercanopy (shrub-interspace, Shr-Int) plots at the Castlehead site (**a**) and bare ground (bare soil plus rock cover) and sediment yield for unburned (Unb) and cut treatment (Cut) tree and intercanopy plots across all study sites (Castlehead, Marking Corral, and Onaqui) (**b**). The relationship in runoff and sediment yield (**a**) demonstrates the initial (1 yr) impact of burning on sediment availability and elevated sediment delivery (for tree coppices in this study) as commonly reported in fire studies (Pierson and Williams, 2016). The relationship in bare ground and sediment yield (**b**) shows the typical increase in sediment yield where bare ground exceeds 50-60% as commonly reported for rangelands (Pierson et al., 2008, 2009; Williams et al., 2014b). Figures modified from Pierson et al. (2013) and Williams et al. (2014a).

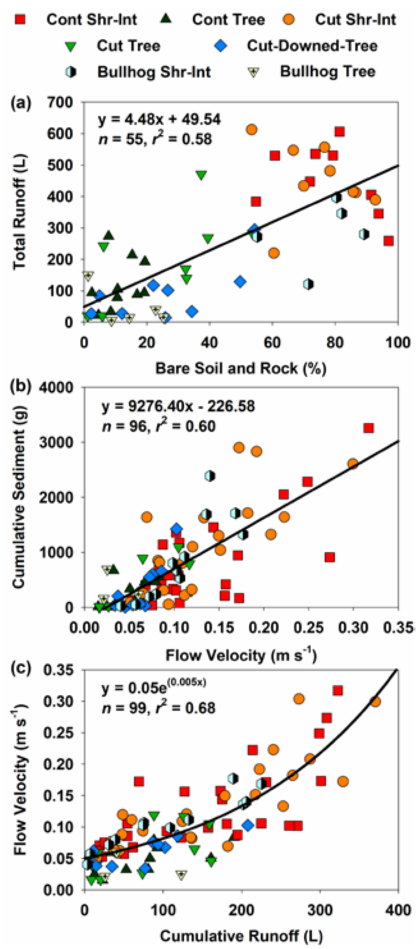

Figure 5. Example relationships/correlations in runoff and bare ground (bare soil plus rock cover; **a**), cumulative sediment and overland flow velocity (**b**), and overland flow velocity and runoff (**c**) derived from a subset of the overland flow dataset for Marking Corral and Onaqui sites, as presented in Williams et al. (2019a). Data from overland flow simulations on untreated/control (Cont) plots, cut treatment (Cut) plots without and with a cut, downed tree (Cut-Downed Tree), and bullhog plots (Bullhog, Onaqui site only) in tree (Tree) and intercanopy (shrub-interspace, Shr-Int) microsites 9 yr after respective tree removal treatments. The data demonstrate that, for the studied conditions, runoff is largely regulated by bare ground, sediment delivery is controlled by flow velocity, and flow velocity is strongly correlated with the amount or runoff.

Table 1 Topography, climate, soil, tree cover, and understory vegetation at the Castlehead, Marking Corral, and Onaqui sites prior to treatments. Data from Pierson et al. (2010, 2015) or Williams et al. (2014a) except where indicated by footnote.

	Castlehead, Idaho, USA (lat 42°26'50"N, long 116°46'39"W)	**Marking Corral, Nevada, USA** (lat 39°27'17"N, long 115°06'51"W)	**Onaqui, Utah, USA** (lat 40°12'42"N, long 112°28'24"W)
Woodland community	western juniper[1]	single-leaf pinyon[2]/Utah juniper[3]	Utah juniper[3]
Elevation (m) - Aspect	1750 – SE facing	2250 – W to SW facing	1720 – N to NE facing
Mean annual precip. (mm)	364[4]	299[4]	298[4]
Mean annual air temp. (°C)	7.4[4]	6.9[4]	9.2[4]
Slope (%)	10-25	10-15	10-15
Parent rock	basalt and welded tuff[5]	andesite and rhyolite[6]	sandstone and limestone[7]
Soil association	Mulshoe-Squawcreek-Gaib[5]	Segura-Upatad-Cropper[6]	Borvant[7]
Depth to bedrock (m)	0.5-1.0[5]	0.4-0.5[6]	1.0-1.5[7]
Soil surface texture	sandy loam, 59% sand, 37% silt, 4% clay	sandy loam, 66% sand, 30% silt, 4% clay	sandy loam, 57% sand, 37% silt, 7% clay
Tree canopy cover (%)[8]	26[1]	15[2], 10[3]	26[3]
Trees per hectare[8]	158[1]	329[2], 150[3]	476[3]
Mean tree height (m)[8]	5.2[1]	2.3[2], 2.4[3]	2.4[3]
Juvenile trees per hectare[9]	28[1]	296[2], 139[3]	154[3]
Shrubs per hectare[10]	2981	12065	4914
Intercanopy bare ground (%)[11]	88	64	79
Common understory plants	*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young; *Artemisia nova* A. Nelson; *Artemisia tridentata* Nutt. ssp. *vaseyana* (Rydb.) Beetle; *Purshia* spp.; *Poa secunda* J. Presl; *Pseudoroegneria spicata* (Pursh) A. Löve; *Festuca idahoensis* Elmer; and various forbs		

[1] *Juniperus occidentalis* Hook.

[2] *Pinus monophylla* Torr. & Frém.

[3] *Juniperus osteosperma* [Torr.] Little.

[4] Estimated from 4 km grid for years 1989-2018 from Prism Climate Group (2019).

[5] Natural Resources Conservation Service (NRCS) (2003).

[6] NRCS (2007).

[7] NRCS (2006).

[8] Trees ≥ 50 cm height, for Castlehead includes data from Williams et al. (2014a) and one additional year.

[9] Trees 5 to 50 cm height, for Castlehead mean based on data from Williams et al. (2014a) and one additional year.

[10] Shrubs ≥ 5 cm height, for Castlehead mean based on data from Williams et al. (2014a) and one additional year.

[11] Intercanopy refers to the area between tree canopies consisting of shrubs, grasses, and interspaces between plants (shrub-interspace zone).

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Table 2. Number of plots sampled by plot type (site characterization vegetation plots and small plot rainfall, large plot rainfall, and overland flow simulation plots) at each study site (Castlehead, Marking Corral, and Onaqui) by treatment and microsite (small plots - tree coppice, shrub coppice, and interspace; large plots and overland flow – tree zone and shrub-interspace zone [intercanopy]) combination each year of the study. Control refers to untreated areas at Marking Corral and Onaqui sites. Unburned refers to areas immediately adjacent to, but outside the wildfire area (burned treatment) at the Castlehead site. Downed tree sub-treatments (cut-downed tree and unburned-downed tree) refer to plots with a single downed tree across each respective plot within the specified associated treatment (cut or unburned). Tree and shrub coppice microsites are areas underneath or previously (prior to treatment) underneath tree and shrub canopy, respectively. Interspace microsites are areas between tree and shrub coppice microsites. Tree zone microsites are areas underneath, or previously underneath, and immediately adjacent (just outside canopy drip line) to a tree canopy. Shrub-interspace zones are the areas between tree canopies, collectively inclusive of shrub coppice and interspace microsites [the intercanopy].

Site Characterization Vegetation Plots (990 m^2)

Year	Treatment	Castlehead	Marking Corral	Onaqui
2006	Control	-	6	9
2007	Bullhog	-	-	3
	Burned	-	3	3
	Cut	-	3	3
2008	Unburned	3	-	-
	Burned	3	-	-
2009	Unburned	3	-	-
	Burned	3	-	-
2015	Bullhog	-	-	3
	Burned	-	3	3
	Cut	-	3	3

Small Plot Rainfall Simulation Plots (0.5 m^2)

		Castlehead			Marking Corral			Onaqui		
Year	Treatment	Tree Coppice	Shrub Coppice	Interspace	Tree Coppice	Shrub Coppice	Interspace	Tree Coppice	Shrub Coppice	Interspace
2006	Control	-	-	-	24	13	23	23	21	36
2007	Control	-	-	-	7	5	8	4	3	3
	Bullhog	-	-	-	-	-	-	10	10	30
	Burn	-	-	-	8	4	8	5	5	10
2008	Control/ Unburned	8	8	8	4	2	4	4	3	3
	Burned	5	5	10	8	4	8	5	5	10
2009	Unburned	3	3	4	-	-	-	-	-	-
	Burned	5	5	10	-	-	-	-	-	-
2015	Control	-	-	-	8	4	6	8	6	6
	Bullhog	-	-	-	-	-	-	5	5	10
	Burned	-	-	-	8	4	6	5	5	10
	Cut	-	-	-	8	4	6	5	5	10

Large Plot Rainfall Simulation Plots (13 m^2)

		Castlehead		Marking Corral		Onaqui	
Year	Treatment	Tree Zone	Shrub-Interspace Zone	Tree Zone	Shrub-Interspace Zone	Tree Zone	Shrub-Interspace Zone
2006	Control	-	-	12	12	18	18
2007	Bullhog	-	-	-	-	4	4
	Burned	-	-	6	6	6	6
	Cut	-	-	-	6	-	6
	Cut-Downed Tree	-	-	-	6	-	6
2008	Unburned	6	6	-	-	-	-
	Unburned-Downed Tree	-	6	-	-	-	-
	Burned	6	6	-	-	-	-

Overland Flow Simulation Plots (~9 m^2)

		Castlehead		Marking Corral		Onaqui	
Year	Treatment	Tree Zone	Shrub-Interspace Zone	Tree Zone	Shrub-Interspace Zone	Tree Zone	Shrub-Interspace Zone
2006	Control	-	-	12	12	18	18
2007	Bullhog	-	-	-	-	4	4
	Burned	-	-	6	6	6	6
	Cut	-	-	-	6	-	6
	Cut-Downed Tree	-	-	-	6	-	6
2008	Control Unburned	6	6	3	3	2	2
	Unburned-Downed Tree	-	6	-	-	-	-
	Burned	6	6	6	6	6	6
2009	Unburned	6	6	-	-	-	-
	Unburned-Downed Tree	-	6	-	-	-	-
	Burned	6	6	-	-	-	-
2015	Control	-	-	5	5	5	5
	Bullhog	-	-	-	-	5	5
	Burned	-	-	5	5	5	5
	Cut	-	-	5	5	5	5
	Cut-Downed Tree	-	-	-	5	-	5

- Indicates not applicable, no plots.

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Table 3. Select foliar cover and ground cover measures on hillslope-scale site characterization plots (990 m^2) in cut and burned treatment areas at the Marking Corral and Onaqui sites 1 yr prior to tree removal (2006) and 1 yr (2007) and 9 yr (2015) after tree removal treatments.

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	Marking Corral			**Onaqui**		
Site characteristic	**Untreated 2006**[1]	**Cut 2007**[2]	**Cut 2015**[2]	**Untreated 2006**[1]	**Cut 2007**[2]	**Cut 2015**[2]
Foliar Cover						
Shrub (%)	14.6	14.3	28.7	3.4	5.0	16.9
Grass (%)	12.4	21.4	30.2	7.3	13.7	27.1
Forb (%)	1.0	3.7	1.4	3.2	12.1	7.4
Ground Cover						
Litter (%)	46.1	46.0	47.6	26.2	41.6	35.8
Rock (%)[3]	22.0	11.3	1.3	29.8	22.3	17.0
Bare soil (%)	26.4	40.5	42.5	37.7	29.1	35.7

	Marking Corral			**Onaqui**		
Site characteristic	**Untreated 2006**[1]	**Burn 2007**[4]	**Burn 2015**[4]	**Untreated 2006**[1]	**Burn 2007**[4]	**Burn 2015**[4]
Foliar Cover						
Shrub (%)	17.7	6.2	8.7	0.9	0.4	10.7
Grass (%)	4.8	10.0	63.1	6.2	3.4	39.7
Forb (%)	0.1	10.6	0.9	3.3	6.0	14.3
Ground Cover						
Litter (%)	47.4	31.4	40.3	34.4	29.7	34.7
Rock (%)[3]	25.4	16.5	12.8	29.0	31.6	21.6
Bare soil (%)	26.8	52.0	39.7	31.1	35.9	29.5

[1] Data from Pierson et al. (2010), but restricted to plots in area subsequently cut or burned at the respective site × treatment combination.

[2] Data from Williams et al. (2019a).

[3] Rock fragments > 5 mm in diameter.

[4] Data from Williams et al. (2020).

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Table 4. Soil texture and bulk density variables and data structure for those measures for all study sites. Abbreviations in the table example are as follows: juniper_cop refers to juniper coppice microsites; shrub_cop refers to shrub coppice microsites; and pinyon_cop refers to pinyon coppice microsites.

Site	Microsite	Percent Sand	Percent Silt	Percent Clay	Bulk Density (g cm^{-3})
Castlehead	interspace	50.4	43.7	5.9	1.04
Castlehead	juniper_cop	65.3	31.5	3.2	0.72
Castlehead	shrub_cop	61.8	34.6	3.6	0.76
Marking Corral	interspace	63.5	32.3	4.3	1.35
Marking Corral	juniper_cop	74.4	23.2	2.3	1.05
Marking Corral	pinyon_cop	68.4	28.3	3.4	1.1
Marking Corral	shrub_cop	59.9	35.4	4.7	1.14
Onaqui	interspace	57.4	36.2	6.5	1.07
Onaqui	juniper_cop	58.9	35.6	5.4	0.83
Onaqui	shrub_cop	56.2	36.9	6.9	1.02

Table 5. Example (subset) of vegetation and ground cover variables and data structure for measures on hillslope-scale site characterization plots (990 m^2) at the study sites. Abbreviations in the table example are as follows: Fol. Cvr. refers to Foliar Cover; and JUOC refers to western juniper (*Juniperus Occidentalis* Hook.).

Plot_ID	Site	Year	Treatment Area	Treated Yes or No	Fol. Cvr. Shrub (%)	Fol. Cvr. Grass (%)	Fol. Cvr. Forb (%)	…	Live Shrubs (> 5 cm) Per Ha	Dead Shrub (>5 cm) per Ha	JUOC Trees (> 0.5 m) Per Ha	JUOC Trees (5-50 cm) Per Ha
SC_CH_BURN1	Castlehead	2008	Burn	Yes	0	5.3	6.3	…	0	722	0	0
SC_CH_BURN2	Castlehead	2008	Burn	Yes	0	3.7	5.7	…	0	611	0	0
SC_CH_BURN3	Castlehead	2008	Burn	Yes	0	5	4	…	0	1389	0	0
SC_CH_UNB1	Castlehead	2008	Unburned	No	0	13.3	6.7	…	222	278	222	5.5
SC_CH_UNB2	Castlehead	2008	Unburned	No	4	26.3	6.7	…	1944	778	162	4.7
SC_CH_UNB3	Castlehead	2008	Unburned	No	14.7	12.3	6.3	…	4056	1944	121	4.2
SC_CH_BURN1	Castlehead	2009	Burn	Yes	0	22	17	…	56	278	0	0
SC_CH_BURN2	Castlehead	2009	Burn	Yes	0	12.7	25.3	…	111	2500	0	0
SC_CH_BURN3	Castlehead	2009	Burn	Yes	0	16.3	26.3	…	0	1833	0	0
SC_CH_UNB1	Castlehead	2009	Unburned	No	1	19.3	2	…	5278	2056	212	5.9
SC_CH_UNB2	Castlehead	2009	Unburned	No	14.7	46.3	7	…	722	56	111	6.2
SC_CH_UNB3	Castlehead	2009	Unburned	No	18.3	39	14.3	…	5667	2056	121	4.6
…	…	…	…	…	…	…	…	…	…	…	…	…
SC_ON_CUT1	Onaqui	2015	Cut	Yes	8.9	41.6	11.3	…	6389	0	0	0
SC_ON_CUT2	Onaqui	2015	Cut	Yes	21	21	7.1	…	10667	0	0	0
SC_ON_CUT3	Onaqui	2015	Cut	Yes	20.8	18.7	3.9	…	10611	0	0	0

Table 6. Example (subset) of rainfall simulation, vegetation, ground cover, and soil variables and data structure for measures on small-rainfall simulation plots (0.5 m^2) at the study sites. Abbreviations in the table example are as follows: Fol. Cvr. refers to Foliar Cover; Grd. Cvr. refers to Ground Cover; WDPT refers to Water Drop Penetration Time; shrub_cop refers to shrub coppice microsites; pinyon_cop refers to pinyon coppice microsites; and juniper_cop refers to juniper coppice microsites.

Plot_ID	Site	Year	Treatment Area	Treated Yes or No	Microsite	Applied Rain DryRun (mm)	Applied Rain WetRun (mm)	Slope (%)	Random Roughness (mm)	…	Fol. Cvr. Shrub (%)	Fol. Cvr. Grass (%)	Grd. Cvr. Bare Soil (%)	Grd. Cvr. Rock (%)	WDPT at 0 cm (s)	…
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	48	76	16.3	15	…	51.4	25.7	23.8	8.9	3	…
SP_MC_CONT82	Marking Corral	2006	Control	No	pinyon_cop	48	76	22.2	26	…	18.1	0	0	0	7	…
SP_MC_CONT83	Marking Corral	2006	Control	No	interspace	48	76	12.8	12	…	0	54.3	20.7	47.8	3	…
SP_MC_CONT84	Marking Corral	2006	Control	No	shrub_cop	48	77	12.8	29	…	78.1	19	13.6	4.9	3	…
SP_MC_CONT85	Marking Corral	2006	Control	No	interspace	48	76	20.7	12	…	0	34.3	38.1	30.9	3	…
SP_MC_CONT86	Marking Corral	2006	Control	No	pinyon_cop	47	76	13.6	15	…	0	2.9	0	0	3	…
SP_MC_CONT87	Marking Corral	2006	Control	No	interspace	44	77	9.6	14	…	4.8	35.2	48.9	13	3	…
SP_MC_CONT88	Marking Corral	2006	Control	No	shrub_cop	45	76	11.2	22	…	61.9	18.1	17	3.4	3	…
SP_MC_CONT89	Marking Corral	2006	Control	No	juniper_cop	48	78	9.9	10	…	0	1.9	0	0	38	…
SP_MC_CONT90	Marking Corral	2006	Control	No	juniper_cop	48	78	17.5	12	…	0	26.7	0	1	51	…
SP_MC_CUT91	Marking Corral	2006	Cut	No	interspace	48	78	9.5	4	…	0	0	37.1	61.9	3	…
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
SP_ON_CONT78	Onaqui	2015	Control	No	shrub_cop	46	74	18.1	17	…	42.9	8.6	14.4	27.8	30	…
SP_ON_CONT79	Onaqui	2015	Control	No	interspace	46	74	19.2	13	…	0	7.6	24.1	59.5	3	…
SP_ON_CONT80	Onaqui	2015	Control	No	shrub_cop	47	75	17.5	19	…	72.4	12.4	31.6	16.8	3	…

Table 7. Example (subset) of rainfall simulation, vegetation, ground cover, and soil variables and data structure for measures on large-rainfall simulation plots (13 m^2) at the study sites. Abbreviations in the table example are as follows: Fol. Cvr. refers to Foliar Cover; Grd. Cvr. refers to Ground Cover; Avg. refers to average; juniper_cop refers to juniper coppice microsites; and pinyon_cop refers to pinyon coppice microsites.

Plot_ID	Site	Year	Treatment Area	Treated Yes or No	Microsite	Applied Rain DryRun (mm)	Applied Rain WetRun (mm)	Slope (%)	Random Roughness (mm)	…	Fol. Cvr. Shrub (%)	Fol. Cvr. Grass (%)	Grd. Cvr. Bare Soil (%)	Grd. Cvr. Rock (%)	Avg. Canopy Gap (cm)	Avg. Basal Gap (cm)
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	39	65	11.1	19	…	9.2	8.8	16.3	6.1	100	164
LP_MC_CUT38	Marking Corral	2006	Cut	No	juniper_cop	47	87	12.2	19	…	7.5	8.8	5.4	2	77	157
LP_MC_CUT39	Marking Corral	2006	Cut	No	intercanopy	37	63	10.4	18	…	29.8	18	44.1	5.4	83	121
LP_MC_CUT40	Marking Corral	2006	Cut	No	intercanopy	50	96	9.6	14	…	11.5	8.8	28.1	49.2	59	94
LP_MC_CUT41	Marking Corral	2006	Cut	No	intercanopy	40	67	8.8	18	…	21.4	13.9	27.2	22.8	76	125
LP_MC_CUT42	Marking Corral	2006	Cut	No	intercanopy	46	88	9.5	15	…	18.6	19.7	24.1	31.2	86	131
LP_MC_CUT43	Marking Corral	2006	Cut	No	pinyon_cop	39	72	9.3	20	…	0.3	3.4	0	0.7	428	499
LP_MC_CUT44	Marking Corral	2006	Cut	No	pinyon_cop	50	93	8.1	18	…	0.7	1.7	0	1	427	435
LP_MC_CUT45	Marking Corral	2006	Cut	No	pinyon_cop	46	94	9.1	15	…	10.8	4.4	0	1.4	113	168
LP_MC_CUT46	Marking Corral	2006	Cut	No	pinyon_cop	47	83	13	21	…	9.8	8.5	1	3.7	127	243
LP_MC_CUT47	Marking Corral	2006	Cut	No	intercanopy	41	80	12.1	25	…	26.9	19.4	32.9	29.5	69	110
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
LP_CH_BURN28	Castlehead	2008	Burn	Yes	juniper_cop	43	77	15.2	12	…	0	3.7	33.6	50.2	43	101
LP_CH_BURN29	Castlehead	2008	Burn	Yes	intercanopy	48	87	14.8	22	…	0	5.8	54.2	44.7	36	56
LP_CH_BURN30	Castlehead	2008	Burn	Yes	intercanopy	42	83	14.7	17	…	0	6.8	33.6	54.2	31	42

Table 8. Example (subset) of overland flow, vegetation, and ground cover variables and data structure for measures on overland flow simulation plots (~9 m^2) at the study sites. Abbreviations in the table example are as follows: Avg. refers to average; juniper_cop refers to juniper coppice microsites; and pinyon_cop refers to pinyon coppice microsites.

Plot_ID	**Site**	**Year**	**Treatment Area**	**Treated Yes or No**	**Microsite**	**Avg. Width 15 L min^{-1} at 3m (cm)**	**Avg. Width 30 L min^{-1} at 3m (cm)**	**Avg. Width 45 L min^{-1} at 3m (cm)**	…	**Avg. Velocity 15 L min^{-1} ($m\ s^{-1}$)**	**Avg. Velocity 30 L min^{-1} ($m\ s^{-1}$)**	**Avg. Velocity 45 L min^{-1} ($m\ s^{-1}$)**	**Avg. Canopy Gap (cm)**	**Avg. Basal Gap (cm)**
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	2	10	28	…	-999	0.029	0.036	67	92
RI_MC_CUT38	Marking Corral	2006	Cut	No	juniper_cop	0	30	32	…	0	-999	0.058	78	156
RI_MC_CUT39	Marking Corral	2006	Cut	No	intercanopy	42	33	43	…	0.07	0.122	0.148	70	93
RI_MC_CUT40	Marking Corral	2006	Cut	No	intercanopy	50	38	53	…	0.085	0.127	0.131	55	100
RI_MC_CUT41	Marking Corral	2006	Cut	No	intercanopy	37	61	59	…	0.028	0.067	0.107	59	106
RI_MC_CUT42	Marking Corral	2006	Cut	No	intercanopy	47	61	52	…	0.05	0.066	0.1	86	109
RI_MC_CUT43	Marking Corral	2006	Cut	No	pinyon_cop	0	52	102	…	0	-999	0.038	333	333
RI_MC_CUT44	Marking Corral	2006	Cut	No	pinyon_cop	0	-999	-999	…	0	-999	-999	284	292
RI_MC_CUT45	Marking Corral	2006	Cut	No	pinyon_cop	0	0	-999	…	0	0	-999	131	172
RI_MC_CUT46	Marking Corral	2006	Cut	No	pinyon_cop	0	24	32	…	0	0.033	0.044	88	175
RI_MC_CUT47	Marking Corral	2006	Cut	No	intercanopy	64	64	52	…	0.062	0.098	0.127	79	85
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
RI_ON_CUT131	Onaqui	2015	Cut	Yes	intercanopy	144	148	158	…	0.051	0.084	0.182	46	46
RI_ON_CUT133	Onaqui	2015	Cut	Yes	intercanopy	0	165	82	…	0	0.054	0.073	65	34
RI_ON_CUT134	Onaqui	2015	Cut	Yes	intercanopy	0	29	36	…	0	0.062	0.086	48	58

Table 9. Example (subset) of time series runoff and sediment data from small-plot rainfall simulations (0.5 m^2) at the study sites. Abbreviations in the table example are as follows: Conc. refers to concentration; and shrub_cop refers to shrub coppice microsites.

Plot_ID	Site	Year	Treatment Area	Treated Yes or No	Microsite	Run Type	Runoff Yes or No	Rainfall Rate (mm h^{-1})	Runoff Start Time (mm:ss)	Simulation Time (mm:ss)	Sample Fill Time (s)	Runoff (L min^{-1})	Sediment Conc. (g L^{-1})	Runoff (mm h^{-1})	Sediment Discharge (g s^{-1})
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	Dry_Run	No	64		00:00	0	0.000	0.00	0.000	0.0000
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	Dry_Run	No	64		44:00	0	0.000	0.00	0.000	0.0000
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	Wet_Run	Yes	102	05:11	00:00	0	0.000	0.00	0.000	0.0000
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	Wet_Run	Yes	102	05:11	05:10	0	0.000	0.00	0.000	0.0000
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	Wet_Run	Yes	102	05:11	05:36	49	0.096	0.38	11.520	0.0006
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	Wet_Run	Yes	102	05:11	06:30	60	0.095	0.10	11.436	0.0002
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	Wet_Run	Yes	102	05:11	07:30	60	0.080	0.13	9.552	0.0002
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	Wet_Run	Yes	102	05:11	08:30	60	0.074	0.00	8.840	0.0000
SP_MC_CONT81	Marking Corral	2006	Control	No	shrub_cop	Wet_Run	Yes	102	05:11	09:30	60	0.068	0.30	8.110	0.0003
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
SP_ON_CONT80	Onaqui	2015	Control	No	shrub_cop	Wet_Run	Yes	100	01:50	26:00	120	0.075	6.42	8.968	0.0080
SP_ON_CONT80	Onaqui	2015	Control	No	shrub_cop	Wet_Run	Yes	100	01:50	29:00	120	0.077	6.29	9.250	0.0081
SP_ON_CONT80	Onaqui	2015	Control	No	shrub_cop	Wet_Run	Yes	100	01:50	32:00	120	0.073	6.58	8.751	0.0080
SP_ON_CONT80	Onaqui	2015	Control	No	shrub_cop	Wet_Run	Yes	100	01:50	35:00	120	0.065	6.55	7.783	0.0071
SP_ON_CONT80	Onaqui	2015	Control	No	shrub_cop	Wet_Run	Yes	100	01:50	41:00	120	0.067	6.50	8.026	0.0073

Table 10. Example (subset) of time series runoff and sediment data from large-plot rainfall simulations (13 m^2) at the study sites. Abbreviations in the table example are as follows: Conc. refers to concentration; and juniper_cop refers to juniper coppice microsites.

Plot_ID	Site	Year	Treatment Area	Treated Yes or No	Microsite	Downed Cut Tree Yes or No	Run Type	Rainfall Rate (mm h^{-1})	Runoff Start Time (mm:ss)	Simulation Time (mm:ss)	Sample Fill Time (s)	Runoff (L min^{-1})	Sediment Conc. (g L^{-1})	Runoff (mm h^{-1})	Sediment Discharge (g s^{-1})
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	No	Dry_Run	52	08:15	00:00	0	0	0	0	0
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	No	Dry_Run	52	08:15	08:14	0	0	0	0	0
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	No	Dry_Run	52	08:15	09:05	20	0.294	19.08	1.357	0.094
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	No	Dry_Run	52	08:15	10:08	15	0.464	14.56	2.142	0.113
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	No	Dry_Run	52	08:15	12:08	15	0.627	8.74	2.894	0.091
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	No	Dry_Run	52	08:15	14:08	16	0.476	11.11	2.196	0.088
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	No	Dry_Run	52	08:15	16:08	15	0.625	10.69	2.883	0.111
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	No	Dry_Run	52	08:15	18:08	15	0.554	10.47	2.556	0.097
LP_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	No	Dry_Run	52	08:15	20:08	15	0.609	12.21	2.812	0.124
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
LP_CH_BURN30	Castlehead	2008	Burn	Yes	intercanopy	No	Wet_Run	110	01:09	30:08	15	15.647	4.68	72.216	1.22
LP_CH_BURN30	Castlehead	2008	Burn	Yes	intercanopy	No	Wet_Run	110	01:09	33:08	15	13.819	4.41	63.781	1.015
LP_CH_BURN30	Castlehead	2008	Burn	Yes	intercanopy	No	Wet_Run	110	01:09	36:08	15	14.198	5.78	65.529	1.368
LP_CH_BURN30	Castlehead	2008	Burn	Yes	intercanopy	No	Wet_Run	110	01:09	39:08	15	16.666	5.65	76.919	1.569
LP_CH_BURN30	Castlehead	2008	Burn	Yes	intercanopy	No	Wet_Run	110	01:09	42:08	15	14.282	5.48	65.915	1.305

Table 11. Example (subset) of time series runoff and sediment data from overland flow simulations (~9 m^2) at the study sites. Abbreviations in the table example are as follows: Conc. refers to concentration; and juniper_cop refers to juniper coppice microsites.

Plot_ID	**Site**	**Year**	**Treatment Area**	**Treated Yes or No**	**Microsite**	**Plot Bordered All Sides Yes or No**	**Runoff 15 L min^{-1} Yes or No**	**Runoff 30 L min^{-1} Yes or No**	**Runoff 45 L min^{-1} Yes or No**	**Applied Overland Flow Rate (L min^{-1})**	**Simulation Time (mm:ss)**	**Sample Fill Time (s)**	**Runoff (L min^{-1})**	**Sediment Conc. (g L^{-1})**
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	Yes	Yes	Yes	Yes	15	00:00	30	0.181	13.49
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	Yes	Yes	Yes	Yes	15	00:41	15	0.47	1.62
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	Yes	Yes	Yes	Yes	15	01:11	15	0.628	0.7
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	Yes	Yes	Yes	Yes	15	02:31	15	1.265	0.66
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	Yes	Yes	Yes	Yes	15	03:06	15	1.662	1.04
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	Yes	Yes	Yes	Yes	15	03:41	15	1.976	0.2
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	Yes	Yes	Yes	Yes	30	00:00	15	11.181	15.97
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	Yes	Yes	Yes	Yes	30	00:45	15	14.551	0.61
RI_MC_CUT37	Marking Corral	2006	Cut	No	juniper_cop	Yes	Yes	Yes	Yes	30	02:40	15	18.795	0.29
…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
RI_ON_CUT134	Onaqui	2015	Cut	Yes	intercanopy	No	No	Yes	Yes	45	04:05	20	14.5	5.51
RI_ON_CUT134	Onaqui	2015	Cut	Yes	intercanopy	No	No	Yes	Yes	45	04:55	20	15.215	5.56
RI_ON_CUT134	Onaqui	2015	Cut	Yes	intercanopy	No	No	Yes	Yes	45	05:45	20	15.694	5.49
RI_ON_CUT134	Onaqui	2015	Cut	Yes	intercanopy	No	No	Yes	Yes	45	08:35	20	17.426	5.41
RI_ON_CUT134	Onaqui	2015	Cut	Yes	intercanopy	No	No	Yes	Yes	45	10:35	20	18.678	5.44