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RESEARCH AND OBSERVATORY CATCHMENTS: THE LEGACY AND THE FUTURE

WILEY

The San Dimas experimental forest: Hydrologic research in semiarid steepland terrain

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Abstract

The San Dimas Experimental Forest (SDEF) is located in southern California and is representative of the chaparral shrublands of the Southwest USA. Chaparral – including genera of *Ceanothus*, *Adenostoma*, *Quercus*, *Salvia* and *Arctostaphylos* – is a dense, drought-tolerant vegetation assemblage with a closed canopy 3–5 m in height. Chaparral is a fire-prone ecosystem and wildfires have burned the SDEF about every 40 years. The SDEF was established in 1933 to quantify the water cycle in a steep, semiarid landscape. Study catchments range in size from 15 to 1160 ha and measurements of stream runoff are made in a nested weir and flume arrangement to account for the very flashy flows. Apart from native chaparral vegetation, streamflow measurements in these study watersheds have also quantified the hydrologic response of vegetation type-conversion and fire. Innovations in hydrologic monitoring developed on the SDEF include a critical depth flume (the San Dimas flume) and tilted rain gages to better sample precipitation in mountainous terrain. Subsurface runoff and plant water relations have been measured in a large lysimeter complex. Water quality monitoring shows that stream water in the SDEF has very high levels of nitrate, derived from atmospheric deposition of chronic air pollution, that approach the Federal EPA standard of 10.0 mg L^{-1} for nitrate-N. Spreadsheets of rainfall and streamflow (from 1938 to 2015) – the San Dimas Experimental Forest hydrologic database – may be found at the right-hand side of the web page at https://www.fs.fed.us/psw/ef/san_dimas/index.shtml. Hard copy charts, tables and other records associated with the foregoing data streams are available from the USDA Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, California, 92501 USA or at pete.wohlgemuth@usda.gov.

KEYWORDS

catchment studies, chaparral vegetation, data availability, data sets, research history, semiarid climate, steepland topography, water quality

1 | DATA SET NAME

The San Dimas Experimental Forest hydrologic database.

2 | INTRODUCTION

The San Dimas Experimental Forest (SDEF) is a nearly 7000 ha research preserve that is representative of the chaparral shrublands of the Southwest USA. Administered by the U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, the SDEF is located in a front range of the San Gabriel Mountains about 45 km northeast of Los Angeles, California (34.200° latitude, −117.750° longitude; Figure 1). The SDEF was established in 1933 to quantify the water cycle in a steep, semiarid landscape, with a mandate to investigate how to increase water yield for downstream agriculture, industry and domestic water supply (Dunn et al., 1988). Data has been

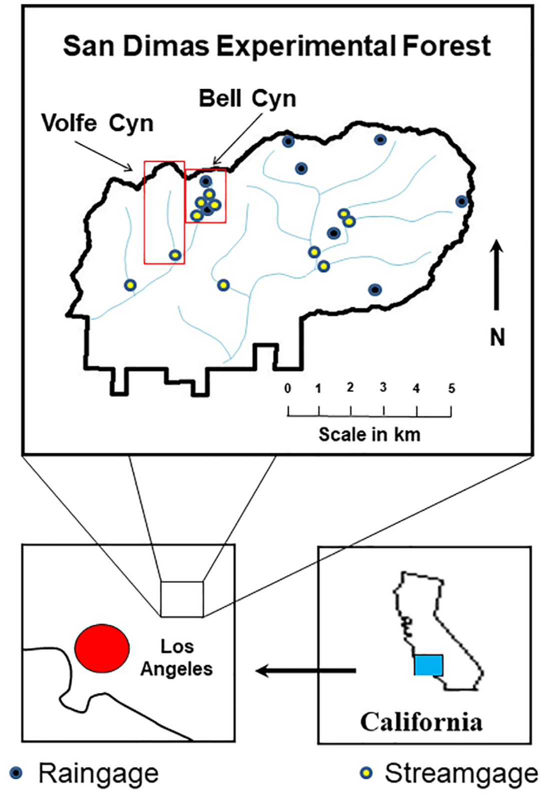

FIGURE 1 Location map of the San Dimas experimental Forest. Note locations of raingages and streamgages with digital records

FIGURE 2 Chaparral vegetation in the San Dimas experimental Forest. Forest boundary is the ridge in the middle ground. Grassy areas in the foreground are watersheds that were type-converted in the early 1960s

collected on rainfall and stream runoff for over 85 years, covering a wide variety of weather conditions, which potentially contain surrogates of expected future values for global climate change modelling. In addition, the site is analogous to Mediterranean-type ecosystems across the globe and the data would be useful for hydrologic comparisons including rainfall/runoff studies. The SDEF continues to measure meteorological parameters, precipitation and streamflow, providing a long-term research platform for catchment studies, and hosts a variety of university and non-governmental organization (NGO) cooperators.

3 | SITE DESCRIPTION

Topography in the SDEF consists of a highly dissected mountain block with narrow, steep-walled canyons (slope angles average 68%) and steep channel gradients. Elevations in the study area range from 450 to 1700 m. Bedrock geology is dominated by tectonically uplifted Precambrian metamorphics and Mesozoic granitics that produce shallow (10–30 cm), azonal, coarse-textured soils (Dunn et al., 1988).

The SDEF experiences a Mediterranean climate, characterized by cool, moist winters and hot, dry summers. Mean monthly temperatures range from 9°C to 31°C (Dunn et al., 1988). Mean annual precipitation, falling almost exclusively as rain, is 714 mm (85-year record), but rain during individual years can range from 252 to 1848 mm. Over 90% of the average annual precipitation falls between the months of November and April, with 10% of the storms producing over 50% of the total rain (Wohlgemuth, 1996).

Native vegetation in the SDEF consists primarily of mixed chaparral (Figure 2). Chaparral is a dense, drought-tolerant shrubland with a closed canopy 3–5 m in height. Plant cover on south-facing slopes ranges from dense stands of chamise (*Adenostoma fasciculatum*) and ceanothus (*Ceanothus* spp.) to more open stands of chamise and sage (*Salvia* spp.). North-facing hillsides are dominated by scrub oak (*Quercus berberidifolia*) and ceanothus, with occasional hardwood trees – live oak (*Quercus agrifolia*) and California laurel (*Umbellularia californica*) – occurring on moister shaded slopes and along the riparian corridors (Wohlgemuth, 1996). Chaparral is a fire-prone ecosystem and wildfires have burned the SDEF about every 40 years (1919, 1960, 2002).

4 | CATCHMENT STUDIES

Seventeen catchments were instrumented for streamflow in the mid-1930s: 10 larger watersheds (300–1160 ha) and seven smaller watersheds (15–40 ha). Watershed characteristics for catchments with digital hydrologic records are listed in Table 1. Stream runoff was measured in a nested weir and flume arrangement (Figure 3) to account for the very flashy flows (Dunn et al., 1988). Eight of the larger watersheds and three of the smaller watersheds were decommissioned after a wildfire in 1960 when subsequent floods and debris flows destroyed the low-flow weirs. In addition, 25 micro-catchments, 1–3 ha in size, were established in 1960 specifically to monitor the hydrologic and sediment yield response of various post-fire erosion control treatments (Dunn et al., 1988).

In the late 1950s to early 1960s, the vegetation in two small watersheds in Bell Canyon (Figure 1) was type-converted from native

TABLE 1 Characteristics of watersheds with digital streamflow records on the San Dimas experimental forest

Watershed	Area (ha)	Outlet coordinates	Aspect	Elevation range (m)	Stream order[a]
Wolfskill	640	34.178, −117.754	W	535–1650	4
Fern	580	34.196, −117.738	W	765–1655	4
Upper East Fork	565	34.197, −117.733	SW	790–1700	5
North Fork	1160	34.181, −117.753	S	545–1385	6
West Fork	400	34.173, −117.775	S	545–915	5
Volfe	300	34.184, −117.796	S	590–1085	4
Monroe	360	34.178, −117.807	S	525–1085	5
Bell1	34	34.192, −117.779	SW	744–1050	3
Bell2	39	34.201, −117.780	S	756–1035	3
Bell3	25	34.200, −117.780	SE	756–1075	3
Bell4	15	34.198, −117.782	SE	735–1024	2

[a]Strahler (1957) stream order based on contour crenulations from 1:24 000 scale map sheets.

FIGURE 3 Gaging station at Volfe watershed. Note removable 90° v-notch weir in the throat of a 2.438 m (8 foot) San Dimas flume. (photo courtesy of Robert Lockwood)

chaparral to a mixture of grasses in an attempt to increase water yield (Bentley, 1961). In theory, the shallow-rooted grasses would use less water than the deep-rooted chaparral vegetation. Results indicated that type-converted catchments did produce more water than an adjacent untreated control watershed, but with considerable environmental degradation (Wohlgemuth, 2015).

Increased runoff after fire has long been recognized in southern California and other fire-prone ecosystems worldwide. Following a 1960 wildfire, the hydrologic response in 300 ha Volfe Canyon (Figure 1) documented that both peak flows and flow volumes increased by four orders of magnitude over pre-fire storms of similar size (Wohlgemuth, 2015).

5 | HYDROLOGIC INSTRUMENTATION

Rainfall on the SDEF was originally measured in non-recording bucket gages that were emptied after every storm. Eventually, mechanical weighing bucket gages were installed at eight key locations around the SDEF that generated charts of rainfall accumulation by a pen trace on a rotating drum. Oil was placed in the weighing bucket to prevent evaporation. Data from these eight weighing bucket raingages from 1933 to 1999 are summarized by storms, with event number, start dates and times, end dates and times and accumulation in inches (spreadsheet SDEF Rainfall Storms with tabs for each raingage). In addition, rain charts from these eight weighing bucket raingages from 1975 to 2015 have been read manually to include start/stop times and durations, 15-min, 30-min and 1-h intensities as well as daily, storm, monthly and annual rainfall accumulations in millimetres (spreadsheet SDEFRainfall with tabs for each raingage). Data accuracy is to 0.254 mm over a collection period (usually 1 week). Starting in 2018, weighing bucket gages are being replaced on the SDEF with electronic tipping bucket gages.

Streamflow is measured as stage height and calculated as litres per second based on rating curves developed for each instrument (90° v-notch weir, 120° v-notch weir, 0.9144 m [3 foot] San Dimas flume, 2.438 m [8 foot] San Dimas flume, or 3.048 m [10 foot] San Dimas flume). A technician manually directs the flow by a gate or winch to an individual instrument based on expected flow volumes. Stage height is measured in a stilling well using a mechanical float-driven water level recorder that produces a pen trace on a continuous chart paper roll. Charts from 1938 to 2002 were manually read at 6-h intervals and at inflection points in the hydrograph to develop digital spreadsheets of date, time, stage height and discharge (spreadsheets for each of 11 different catchments with tabs for each year). The spreadsheets include the watersheds listed in Table 1, some of which were discontinued in 1960. All the watersheds are in native chaparral vegetation except Bell1 and Bell2, which were type-converted to grasses following a wildfire in 1960. Streamflow data for the 25 micro-catchments established after the 1960 wildfire are not yet included in the database. Data accuracy is to 0.05 centimetre or 0.02–

0.05 litres per second for weir measurements and 0.5–1.0 litres per second for flume measurements.

6 | OTHER HYDROLOGIC STUDIES

Several innovations in hydrologic monitoring were developed on the SDEF, including a critical depth flume (the San Dimas flume) that was unaffected by velocity approach or bedload (Wilm et al., 1938) and tilted rain gages for better precipitation sampling in mountainous terrain (Hamilton, 1954). From 1940 to 1945 the Experimental Forest had a network of over 450 rain gages with densities that approached one gage per hectare in some study areas (Dunn et al., 1988).

A large lysimeter complex was built in the late 1930s to measure soil moisture, percolation, groundwater flow, evapotranspiration and water use by different species of vegetation (Patric, 1961). However, significant design flaws led to questions of the applicability of these results to actual field conditions, and the lysimeters were eventually abandoned (Dunn et al., 1988).

Water quality sampling began at San Dimas in the 1980s. High rates of atmospheric N deposition produced by chronic air pollution in southern California has led to measured surface water levels of nitrate that approach the Federal EPA standard of 10.0 mg L^{-1} for nitrate-N (Fenn et al., 2003). Fire and management history (type-conversion) can further increase nitrate levels in SDEF stream water (Riggan et al., 1985).

7 | OWNERSHIP, FUNDING AND COOPERATORS

The San Dimas Experimental Forest hydrologic database was developed by the author as a U.S. Department of Agriculture, Forest Service federal employee and is available to all. Ownership of the database resides with the U.S. Department of Agriculture, Forest Service. Funding for the basic hydrologic instrumentation comes exclusively from the United States government, which also employs both the database developer and the webmaster. Cooperators, primarily from local universities, are self-funding (apart from rainfall and streamflow monitoring), working on the SDEF under a research permit. Manuscripts and reports from the cooperators, along with those from Forest Service employees, may be found in the Publications file located at the right-hand side of the web page at https://www.fs.fed.us/psw/ef/san_dimas/index.shtml.

8 | DATABASE AND DATA AVAILABILITY

Digital records of rainfall and streamflow comprise the San Dimas Experimental Forest hydrologic database. Spreadsheets of rainfall and stream runoff may be found at the right-hand side of the web page at https://www.fs.fed.us/psw/ef/san_dimas/index.shtml. More data will be added to this website as they become available in electronic form. Meteorological records have been collected on the SDEF since the 1930s by a variety of instruments but are mainly summaries or tabular raw data. Hard copy charts, tables and other records associated with the foregoing data streams are available from the USDA Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, California, 92 501 USA or at pete.wohlgemuth@usda.gov.

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CONFLICT OF INTEREST

The author has no conflict of interest, financially or otherwise, with the San Dimas Experimental Forest or the data sets presented.

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