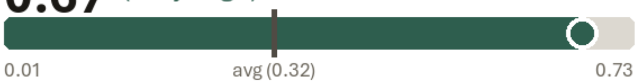
San Rafael Groundwater Basin Profile

ARIZONA TRI-UNIVERSITY
RECHARGE AND WATER RELIABILITY PROJECT

Basin Summary Statistics

Size[1]: 229 square miles
Elevation[2]: Range: 4,596-9,098 ft; Median: 5,216 ft
Top 3 land cover types by area[3]: Shrub/Scrub (59%), Evergreen Forest (24%), Grassland Herbaceous (15%)
Major surface watershed(s)[4]: Upper Santa Cruz and Upper San Pedro
Groundwater subbasins[1]: None
Groundwater-derived streamflow fraction[5]:

0.67 (Very High)



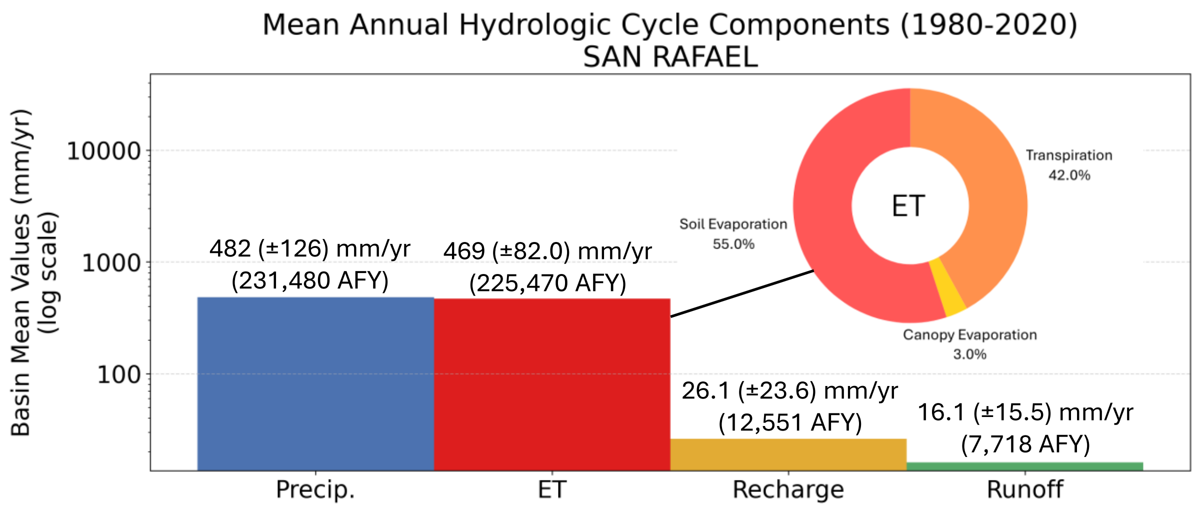


Figure 1 (above). Bar chart showing Noah-MP modeling results of the historical mean annual hydrologic cycle components (precipitation [P], evapotranspiration [ET], natural recharge, and runoff) in the basin from 1980-2020.[6] ET is partitioned into soil evaporation, canopy evaporation, and transpiration. It is possible for ET to be greater than P when there are other sources such as groundwater, surface water, or water in storage.

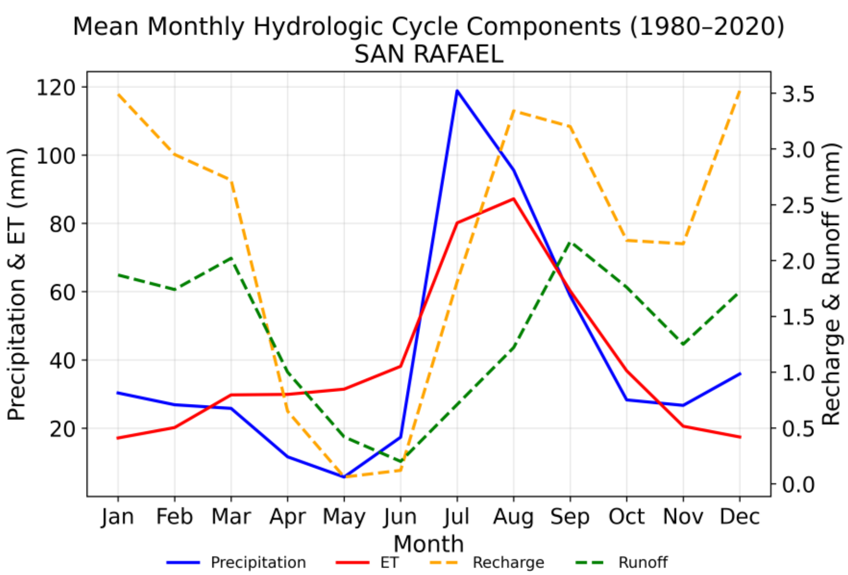


Figure 2. Graph showing monthly mean precipitation, ET, recharge, and runoff for the groundwater basin (1980-2020) from Noah-MP modeling results.[6]

Precipitation (P) in the San Rafael basin is affected by the North American Monsoon during the summer months and exceeds evapotranspiration (ET) on annual timescales. The greatest atmospheric losses occur during the summer months, and ET is greater than P from mid-February to mid-June. Soil evaporation makes up 55.0% of total ET in the basin, while transpiration comprises 42.0% and canopy evaporation accounts for the remainder (3.0%). Natural recharge (26.1 mm/yr) and runoff (16.1 mm/yr) are highest in the winter months (when evaporative demand is low), and during the late summer as a result of monsoon precipitation. Groundwater supplies an estimated 67% of total streamflow in the San Rafael basin.

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Figure 3 (below). Gridded depiction of mean annual water fluxes across the groundwater basin from Noah-MP modeling (1980-2020): (a) precipitation, (b) evapotranspiration, (c) recharge, (d) runoff.[6] Major cities/towns[7] and Native American Reservation boundaries[8] are shown (as applicable) to help orient the reader.

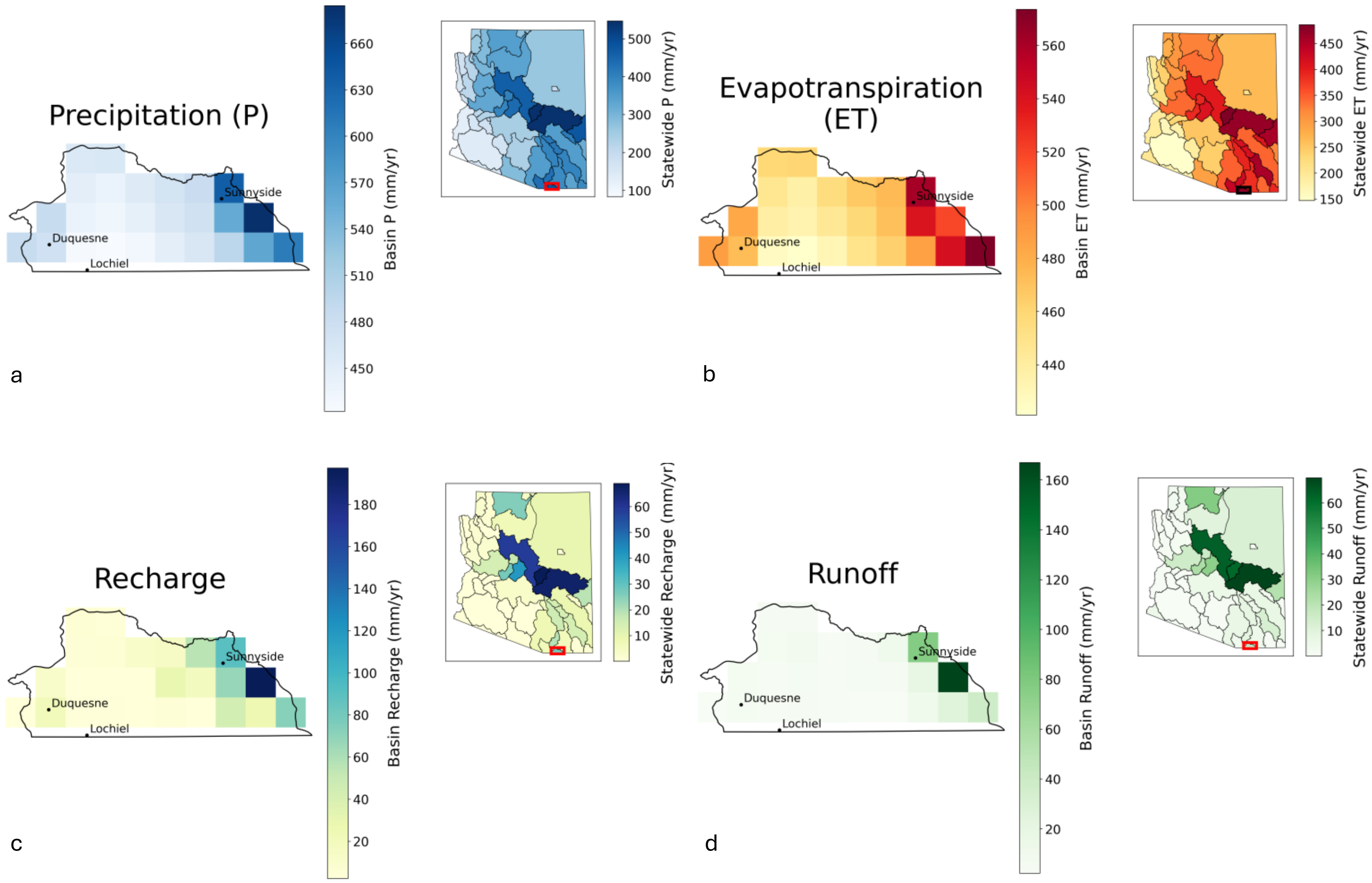
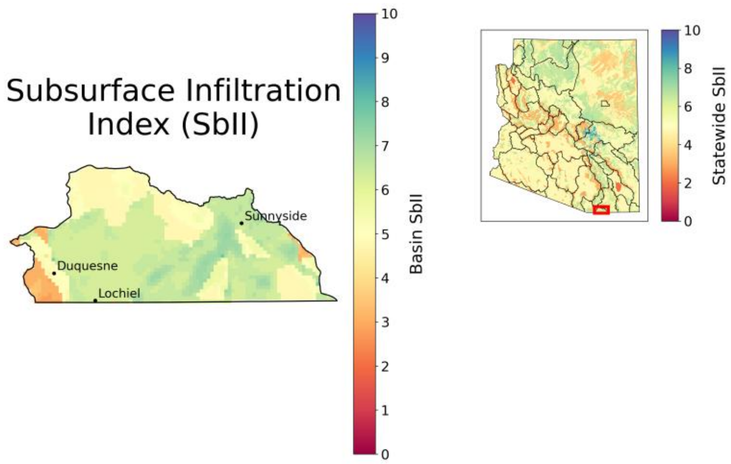


Figure 4 (below). Subsurface infiltration index (SbII) showing infiltration potential of the subsurface across the groundwater basin on a scale of 1-10 based on geologic features.[9]



Precipitation (P) in the San Rafael basin is greatest in the Huachuca Mountains, where P can exceed 650 mm/yr. ET (~530 mm/yr), natural recharge (>100 mm/yr), and runoff (>100 mm/yr) are also highest in this region of the basin. Infiltration potential is relatively high across the basin due to faults near the Huachuca Mountains and generally high permeability of the alluvial deposits across much of the basin.

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Climate Change Projections:
Changes in Temperature, Precipitation, ET, Recharge, and Runoff
(2060-2099 vs. 1981-2020)

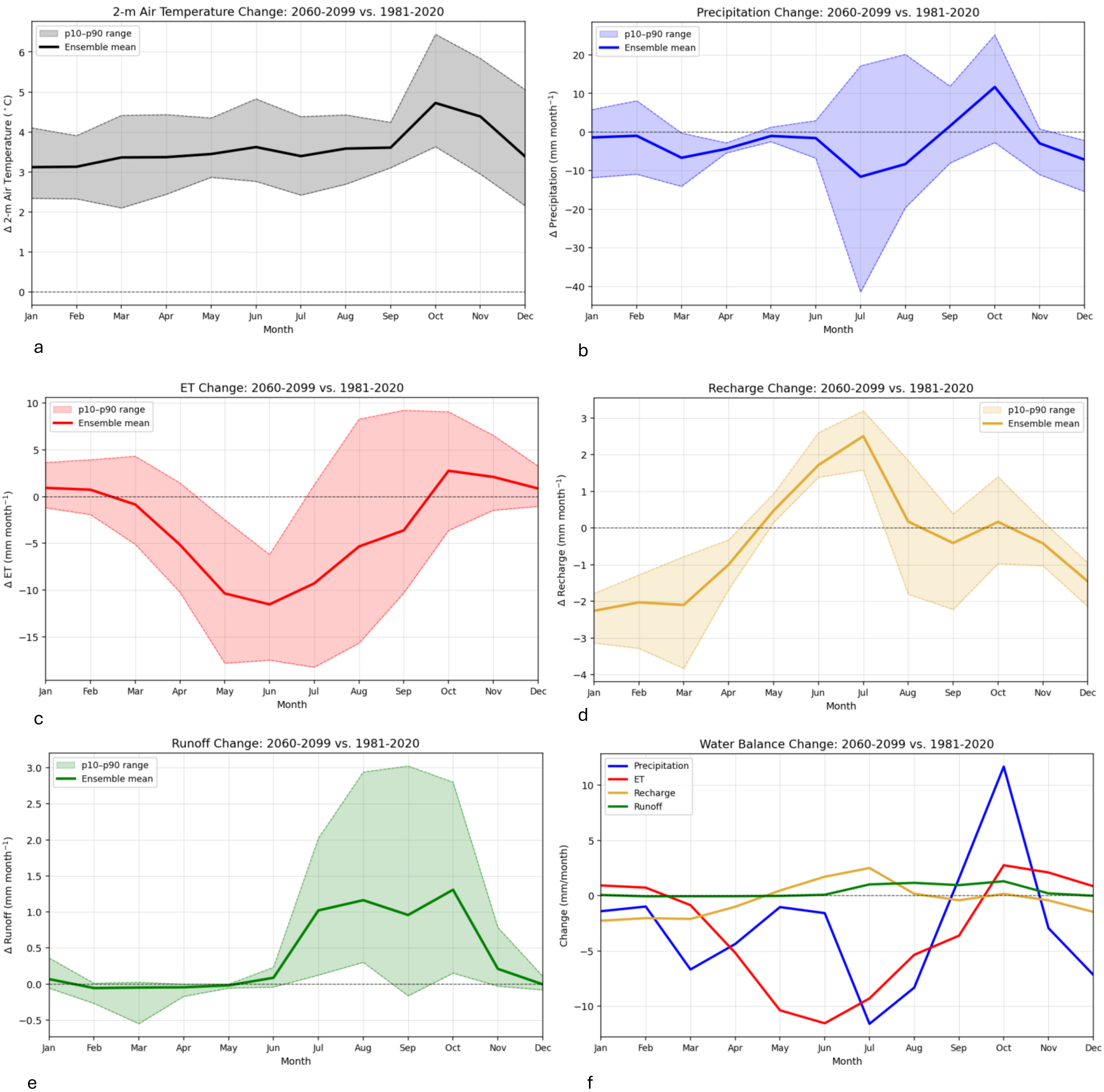

Figure 5. Plots (a)-(e) show projected changes in (a) temperature, (b) precipitation, (c) evapotranspiration (ET), (d) natural recharge, and (e) runoff statewide, comparing end of the 21st century to the historical record from 1981-2020 under the IPCC Scenario SSP3-7.0.[10] Plot (f) shows the change in the water balance components (P, ET, recharge, and runoff) on a single graph for direct comparison. The analysis uses 14 dynamically downscaled global climate models (GCM) at 9-km resolution and the Noah-MP land surface model. The ensemble mean of the 14 GCMs is shown in bold for each component of the hydrologic cycle, with the 10-90th percentile shaded to show model projection uncertainty.

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Climate change projections across the San Rafael basin show that most of the year will be drier (4-41%) compared to the baseline, except for October, which is projected to be 39% (12 mm) wetter. A wetter October is consistent with a projected increase in extreme events associated with hurricane and tropical cyclone activity by the end of the century. The months with the highest natural recharge (January-April) are projected to have declines of 46-58% (-1.0 to -2.3 mm/month). Despite less water loss (shown as an increase from the baseline in Figure 8(d)), recharge is projected to be negative from May-June (-0.32 to -0.77 mm/month).* While remaining below 1.5 mm/month, runoff is projected to increase by 0.98 to 1.3 mm/month in July-October by the end of the century. Projected increases in temperature range from approximately 3.2 °C in January-February to 4.8 °C in October. Higher temperatures and greater water availability from precipitation lead to a projected 6% (2.8 mm) increase in evapotranspiration (ET) in October compared to the baseline period, while less water availability April to September leads to projected declines in ET (14-30%, or -3.7 to -12 mm) during the warmer months.

*Projected negative recharge values are attributed to increased capillary rise from the aquifer through the vadose zone due to climate factors, resulting in water loss from the system. Because the Noah-MP model does not include groundwater pumping, this indicates that climate-driven factors play a significant role in groundwater storage decline in Arizona.

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