water
MDPI

Assessing Groundwater Withdrawal Sustainability in the Mexican Portion of the Transboundary Santa Cruz River Aquifer

Supplementary Materials

Evaluation of precipitation spatial disaggregation and hydrologic model streamflow simulations.

In this supplemental document, we provide an evaluation study of the precipitation spatial disaggregation and the hydrologic model streamflow simulations. The spatial distribution of precipitation over the basin as represented by TerraClimate, a 1958–2020 monthly ~4 km^2 climatological dataset with global coverage [36] is shown in Figure S1 for the annual, summer (JJAS) and winter (NDJFM). A substantial spatial distribution over the Upper Santa Cruz River Basin (USCRB) that is mainly associated with topographic features is shown in Figure S1.

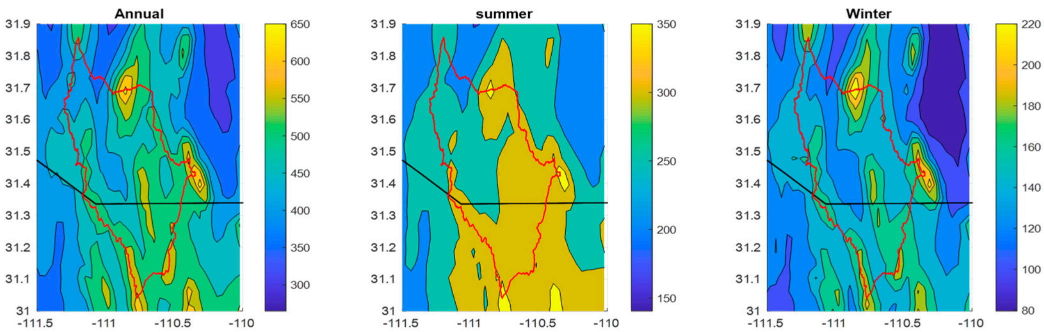

Figure S1. Average annual, summer (JJAS), and winter (NDJFM) rainfall over the USCRB (outlined in red). Data are available from the TerraClimate monthly 4 km^2 1958–2020 dataset.

The association between the observed monthly rainfall of the Nogales 6N rain gauge and its TerraClimate 4 km^2 corresponding grid cell is shown in Figure S2. Although spatial scaling mismatch between the gauge record and the grid cell. It is seen that the TerraClimate agrees fairly well with the observed gauge record, which implies that the Nogales 6N rain gauge was likely included in the derivation of the TerraClimate dataset.

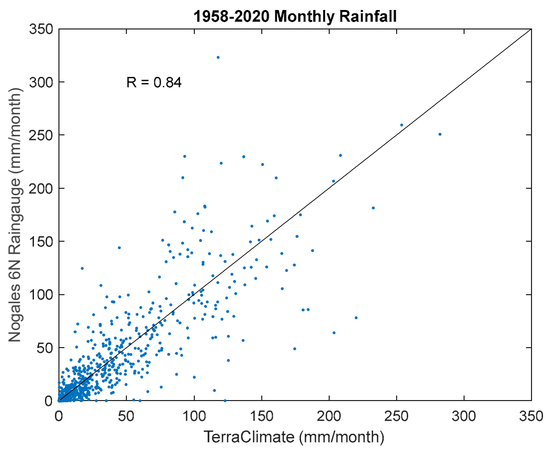

Figure S2. A scattergram of 1958–2020 monthly rainfall of the gauge record from Nogales 6N and the matching grid cell available from the TerraClimate dataset.

To evaluate the performance of the precipitation spatial disaggregation procedure, we identified seven rain gauges from different areas over the USCRB, which have daily rainfall records (Figure S3). Data for five of the rain gauges are available from the National Centers for Environmental Information (NCEI) NOAA and data for the other two gauges are available from CONAGUA. In Figure S4 (summer) and S5 (winter) the seasonal cumulative distributions for the available historical daily data from the seven gauges are compared to the cumulative distributions of the corresponding grid cell that was spatially disaggregated using the Nogales gauge.

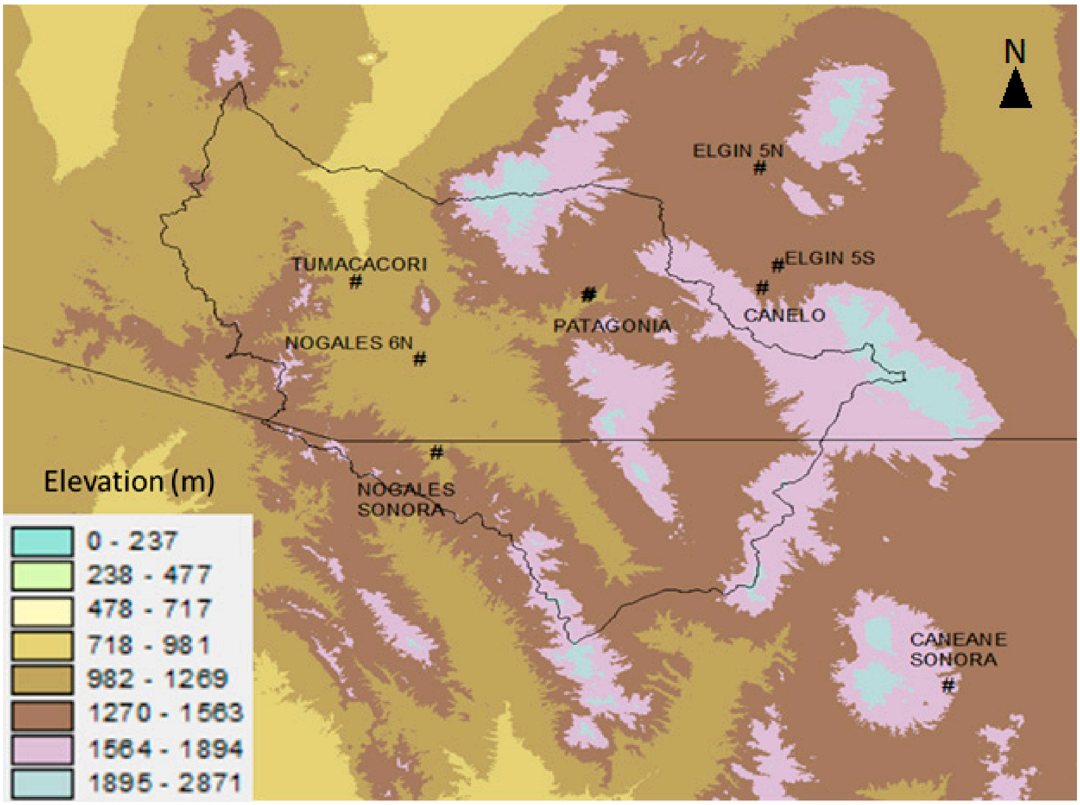

Figure S3. Locations of the of daily rain gauges.

The comparison of the cumulative distributions includes various data spans with durations that were often not included in the analysis of the nominal record of the Nogales gauge (1949–2020). It is seen that the summer and winter cumulative distributions of the interpolated grid cells match well the shape and magnitude of the gauge distributions. An additional evaluation of the interpolated grid cells and the gauge is shown as a scattergram of the seasonal totals at the corresponding dates (Figure S6). Although the scattergram shows a spread along the 1:1 line, it also indicates a clear linear association between the interpolated grid cells and the gauges.

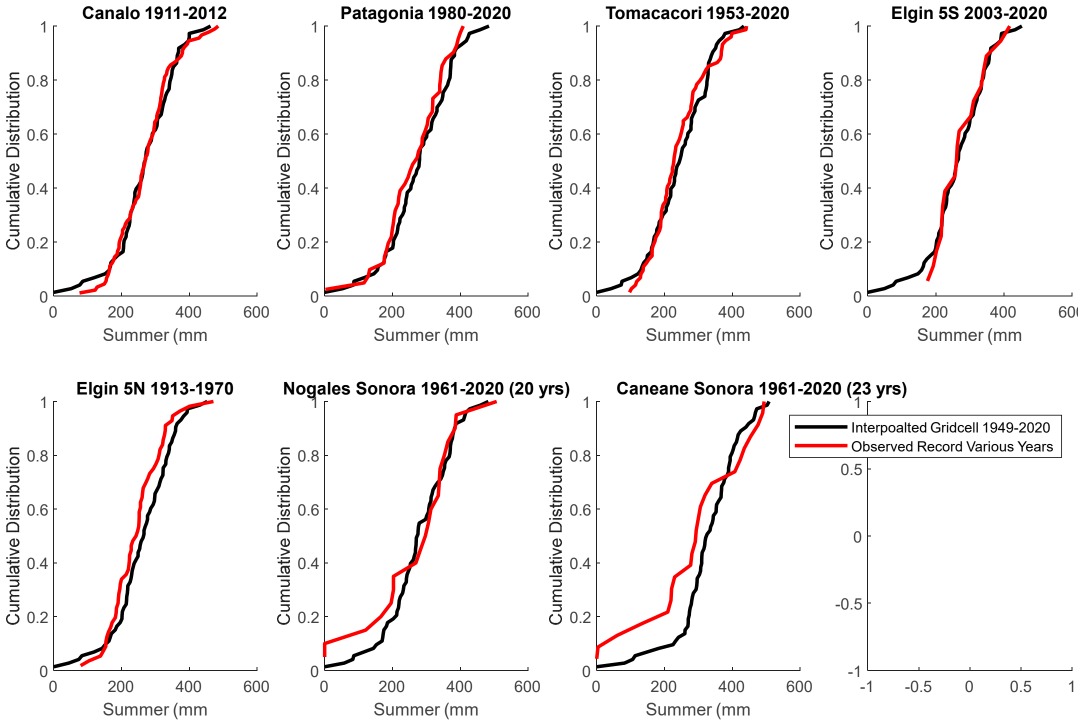

Figure S4. A comparison between the total summer rainfall cumulative distributions of the spatially disaggregated Nogales gauge (black) and seven rain gauge records (red). Note that the seven gauges have different durations, as indicated at the subplots' titles.

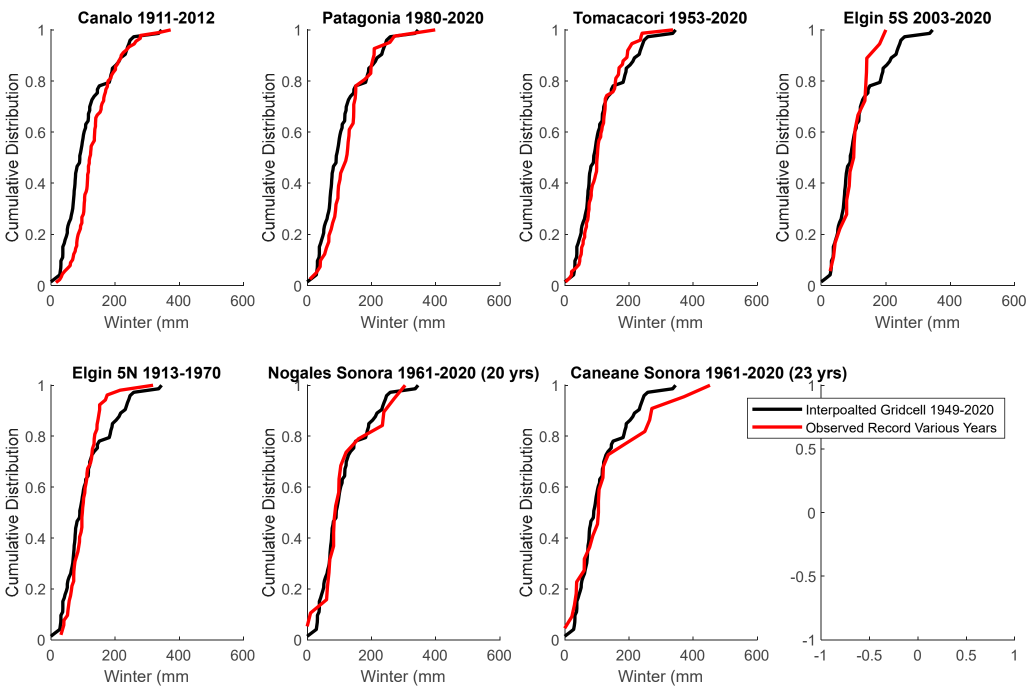

Figure S5. A comparison between the total winter rainfall cumulative distributions of the spatially disaggregated Nogales gauge (black) and seven rain gauge records (red). Note that the seven gauges have different durations, as indicated at the subplots' titles.

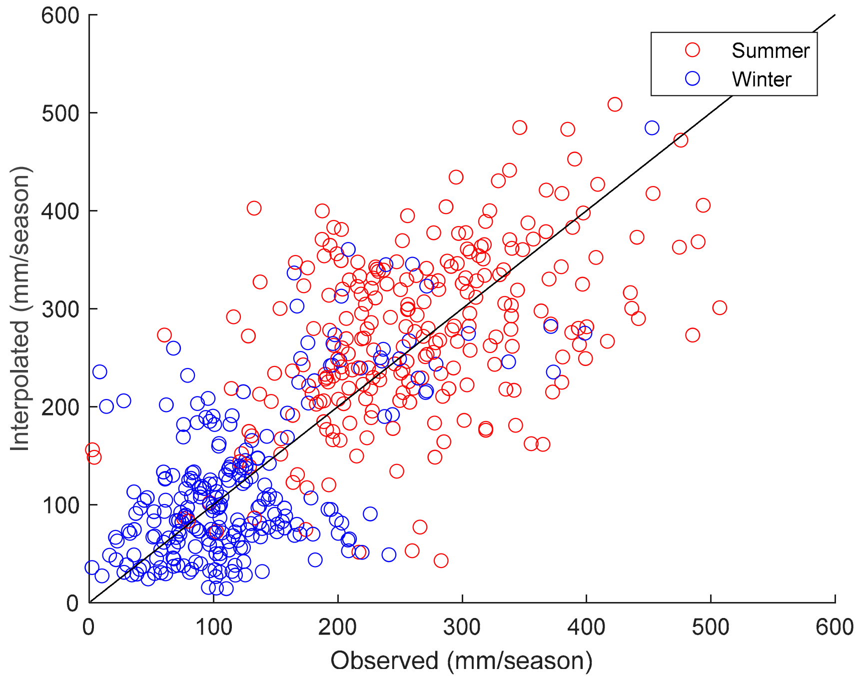

Figure S6. A scattergram of the summer (red) and winter (blue) total precipitation of the spatially disaggregated observed Nogales record compared with matched observed record from the seven gauges.

Hydrologic Model Evaluation

The simulated inflow and outflow from the basin were compared to the historical Santa Cruz River streamflow records that are available from Lochiel (USGS 09480000) and near Nogales (USGS 09480500), respectively. The hydrologic model simulation was carried in hourly intervals for the period 1949–2020, while the evaluation shown in the figures are for the seasonal and annual scales. In Figure S7 the simulated and observed 1949–2020 cumulative distributions of summer, winter and annual (water year) streamflow at Lochiel are compared. While the CDFs of the observation and simulations match well the low flow it seems that the higher seasonal flow are more difficult to match. We note that matching the tail of the seasonal distributions requires an accurate performance during the five wettest seasons. It can be seen that for the wettest season the simulations are slightly underestimate and overestimate during the summer and winter, respectively. These seasonal biases of the low flow are offset when comparing the annual flow, except from the wettest year on record.

Similar to Figure S7, in Figure S8, the comparison is shown for the Nogales gauges, which measures the streamflow out of the Mexican part of the Mexican Santa Cruz River. Overall the seasonal simulations match well the range of observed seasonal flow. It is noted that for both summer and winter the simulation underestimate at the CDF's quantiles of 0.7–0.95 and overestimate the seasonal flow that is larger than 0.95.

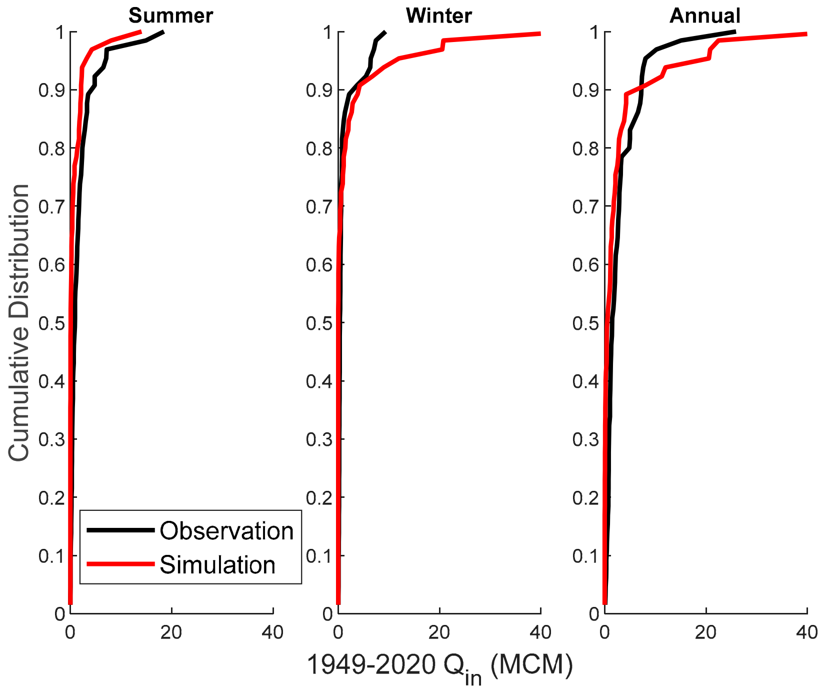

Figure S7. The 1949–2020 cumulative distributions of simulated (red) and observed (black) streamflow on the Santa Cruz River at Lochiel for the summer, winter, and annual.

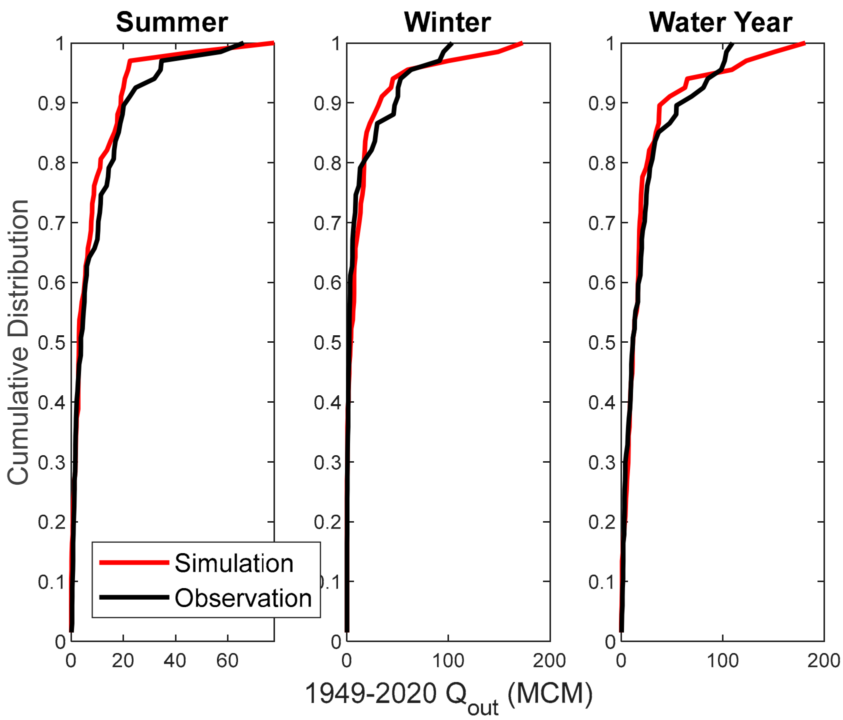

Figure S8. The 1949–2020 cumulative distributions of simulated (red) and observed (black) streamflow on the Santa Cruz River at the Nogales gauge for the summer, winter, and annual.