

Upper Rio Grande Streamflow, Climate, and Recent Increases in Runoff Efficiency

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The Rio Grande headwaters in Colorado (Fig. 1) is a critical water supply for south-central Colorado and much of New Mexico, with treaty obligations to Texas and Mexico. Over recent decades, warming conditions have resulted in a reduction of snowpack, the main source of water from the headwaters. However, over the last 3 decades, despite decreasing precipitation and increasing temperatures, streamflow has not shown a corresponding decrease, and runoff efficiency (the ratio of streamflow to precipitation, or how much streamflow is yielded from precipitation in the headwaters) has increased. This study documents trends in Rio Grande hydroclimate and hypothesizes the reasons for these unexpected results.



Figure 1. Rio Grande watershed (blue/red outline). Rio Grande at the Del Norte CO gage (yellow star) accounts for about 75% of the Rio Grande headwaters streamflow, which in turn supplies about 60%-65% of the river's native flow above Elephant Butte Reservoir in southern New Mexico. Inset shows full Rio Grande basin.

Major Study Findings

1. In the headwaters of the Rio Grande, despite increasing temperatures and decreasing precipitation since 1990, Rio Grande streamflow does not show a correspondingly strong decrease. The trend in runoff efficiency indicates that streamflow has been greater than expected, relative to the basin precipitation, over this period (Fig. 2).

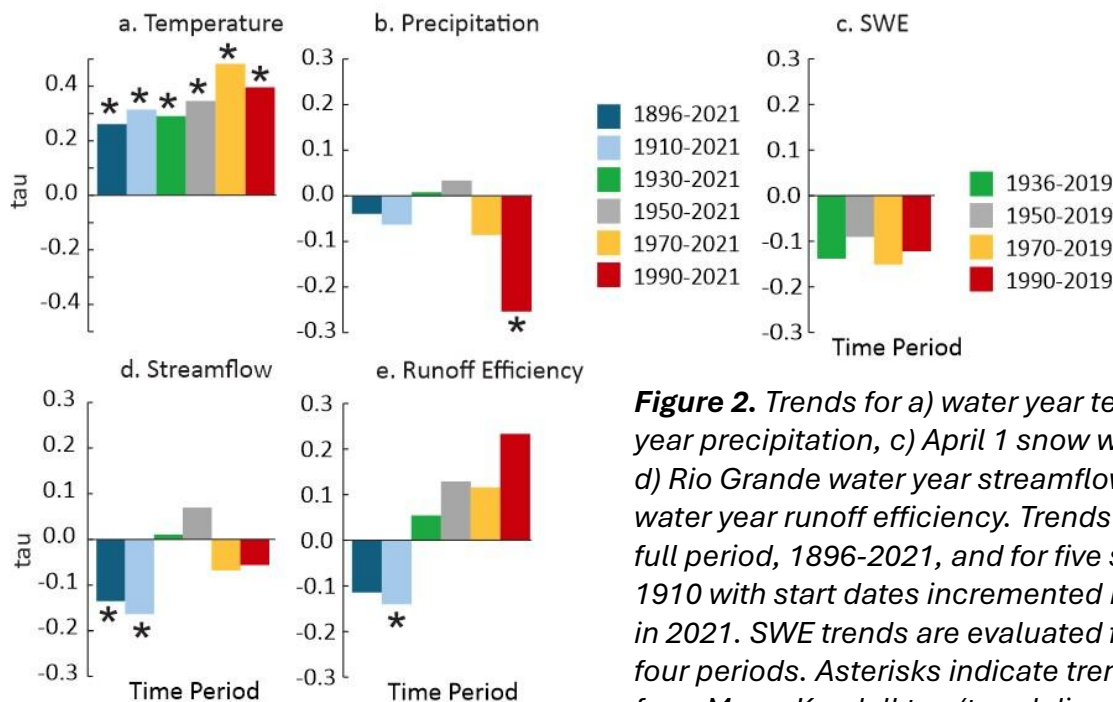


Figure 2. Trends for a) water year temperature, b) water year precipitation, c) April 1 snow water equivalent (SWE), d) Rio Grande water year streamflow, and e) Rio Grande water year runoff efficiency. Trends are evaluated for the full period, 1896-2021, and for five subperiods starting in 1910 with start dates incremented by 20 years and ending in 2021. SWE trends are evaluated from 1936 to 2019 for four periods. Asterisks indicate trend significance ($p < 0.05$) from Mann-Kendall tau (trend direction and strength).

2. Relationships between precipitation, streamflow, temperature and runoff efficiency changed near the end of the 20th century, suggesting that something different has influenced the amount of streamflow resulting from precipitation.

Higher streamflow generally coincides with higher precipitation, and lower streamflow with less precipitation. Since runoff efficiency is the ratio of streamflow to precipitation, it varies accordingly (Figure 3a). Under cooler temperatures (e.g., the early 20th century), runoff efficiency tends to be higher (less water loss to evapotranspiration) while it tends to be lower under warmer conditions (more water loss due to greater rates of evapotranspiration; e.g., the late 20th century)(Figure 3b). However, around 2010 (which reflects the 2001-2010 average in the graph 3a below), runoff efficiency started increasing, while precipitation decreased. Streamflow also decreased, but the decline was less than for precipitation. At the same time, temperatures increased. Under typical conditions, warming and drying climatic conditions would lead to decreases in streamflow and runoff efficiency, so something different is happening here.

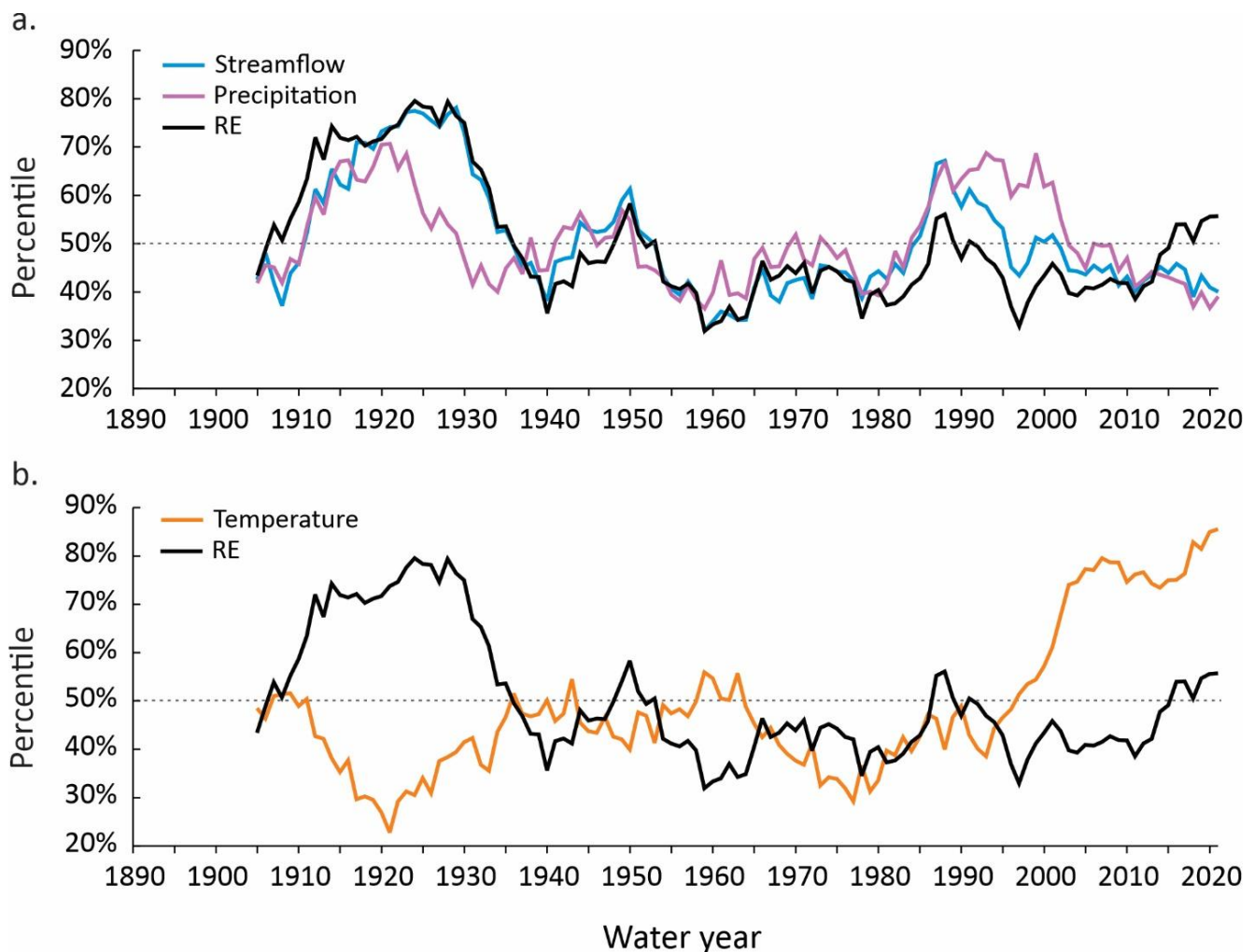


Figure 3. Rio Grande hydroclimatic time series, 1896-2021, smoothed with a 10-year running mean (plotted on last year of the 10-year period), in percentile units (the dotted line shows the median, the 50th percentile). a) water year Rio Grande streamflow (blue line), precipitation (pink line), and runoff efficiency (black line). b) water year temperature (orange line) and runoff efficiency (black line).

3. The recent increase in runoff efficiency coincides with extensive forest mortality due to a spruce beetle epidemic in the Rio Grande headwaters.

While there are likely to be several causes for the unexpected increase in runoff efficiency, one possible cause is related to the impact of widespread forest mortality on runoff. A spruce beetle outbreak, which started about 2005, peaked in 2013 (Fig. 4). By 2014, more than 90% of the spruce-fir forests of the Rio Grande National Forest were dead. Extensive tree death appears to have led to less interception of snow by branches and less uptake of soil water by the trees, resulting in more runoff into streams.

The close correspondence in timing between peak forest mortality and the increase in runoff efficiency makes for a compelling cause, but other factors could have been influential as well. These include earlier snowmelt due to warming, with runoff occurring during a time of the year with lower solar radiation; groundwater inputs to streamflow; and the effects of wildfire on runoff.

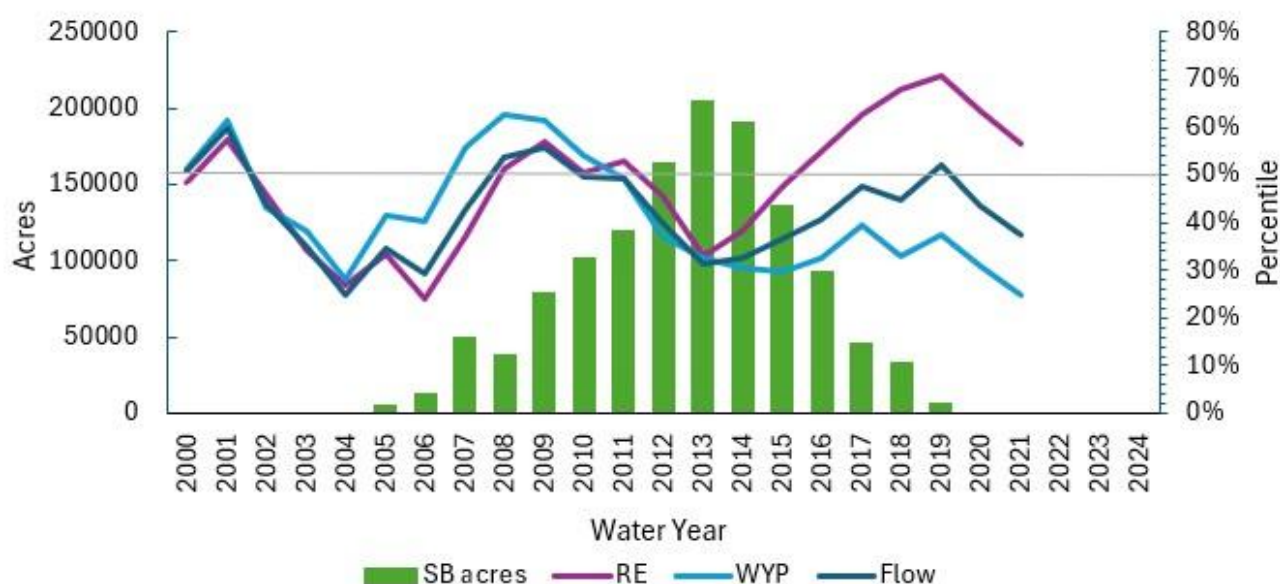


Figure 4. Spruce beetle mortality, in acres, 2004-2024 (green bars), with time series of upper Rio Grande runoff efficiency (purple line), water year total precipitation (light blue line), and Rio Grande water year streamflow (dark blue line), 5-year running means in percentile (plotted on the 5th year), 2000-2021. Dotted horizontal line is the median (50th percentile).

In conclusion:

The recent unexpected increase in Rio Grande headwaters runoff efficiency has resulted in streamflow that is not as low as would be the case if warm temperatures and dry conditions were the only influences on streamflow. It is difficult to parse out exactly what has caused this runoff efficiency increase, but forest mortality due to a spruce beetle epidemic is likely one cause. To the extent that this mortality is a key factor, its influence will be temporary, dependent on the rate of recovery of the forests. Other factors could also be influential. A better understanding of the interacting influences of climate variability and change, hydrology, and landscape scale disturbances will help anticipate Rio Grande water supplies available in the future.

For more information on this study:

Full journal article (**Open Access**):

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Data:

Hydroclimatic data sets used in this study and their sources are as follows: Colorado Division 5 monthly temperature and precipitation data ([Vose et al., 2014](#)), upper Rio Grande regional April 1 SWE ([Pederson et al., 2011](#)), April 1 snow water equivalent (SWE) data ([NRCS, 2025](#)), and Rio Grande nr Del Norte CO streamflow data ([Colorado Division of Water Resources, 2025](#)). Rio Grande runoff efficiency is available from the University of Arizona Research Data Repository (<https://doi.org/10.25422/azu.data.30546389>). Spruce beetle mortality acreage data were obtained from Matt Ethington, Forest Entomologist, Rocky Mountain Region, US Forest Service, USDA.

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Aerial view of the headwaters region of the Rio Grande in southwest Colorado on May 23, 2004. Mitch Tobin, Water Desk. <https://waterdesk.org/multimedia/>

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