Forest Health and Streamflow

Investigating Streamflow Response to Future Climate and Land Cover Change Scenarios in the Rio Grande Headwaters

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Photo credit: Heather Dutton

INTRODUCTION

The timing and amount of water in streams and rivers is influenced by the health of headwaters forests. Like many forested and snow-dominated catchments in the western US, Colorado's Rio Grande Headwaters (RGH) has experienced numerous land cover disruptions in recent decades. Severe drought in the early 2000s, widespread spruce beetle induced forest mortality (~2005-2011), and the West Fork Complex Fire (WFC) of 2013 (**Figure 1**) have raised concerns about streamflow resilience under future climate and land cover disturbance scenarios.

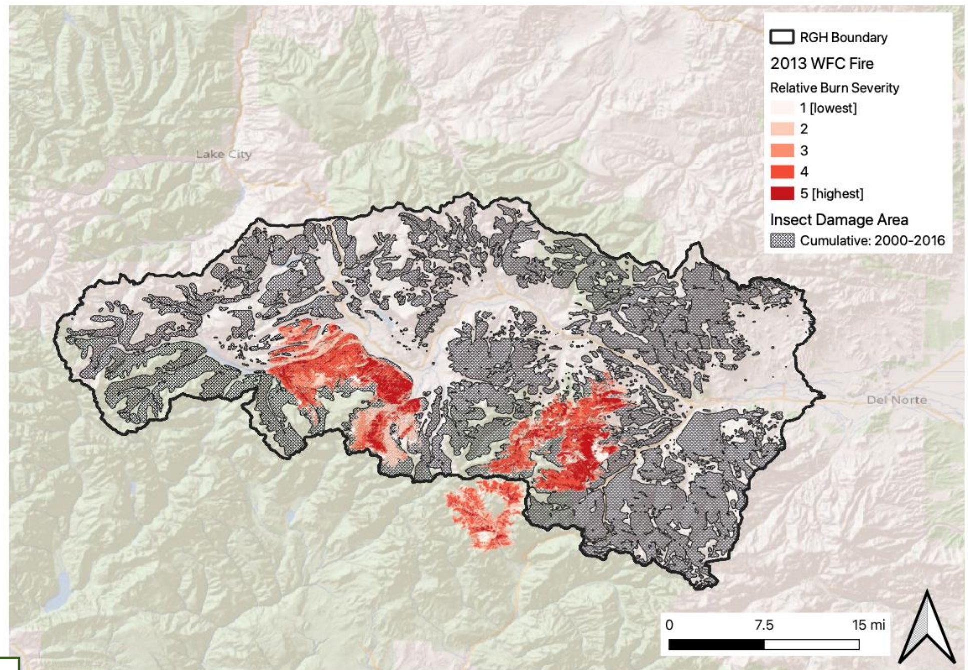

FIGURE 1: FOREST DISTURBANCES IN THE RGH

RESEARCH QUESTIONS

How does the **timing** and **amount** of streamflow respond to forest health disturbances? Disturbances include:

- Climate change (temperature ↑ & precipitation ↓)
- Wildfire
- Wildfire + climate change
- Changes in tree and shrub species composition

WHY MODEL THE RIO GRANDE HEADWATERS?

From a RGH stakeholder perspective → Despite recent forest disturbances, the RGH is not "immune" to future forest disruptions, including wildfire, drought and changes in species composition. These disruptions will likely have implications for future water supplies. Modeling "worst-case-scenarios" may support water management efforts.

From a scientific perspective → Since the RGH has experienced several well-documented forest disturbances in recent decades and has a strong period of streamflow record at the Del Norte stream gauge, it is an "ideal candidate" for studying water supply following both singular and "overlapping" (more than one at a time) disturbances. Results from this work will inform forest disturbance hydrology across the greater western US, where these disturbances are increasing in frequency and size.

MODELING METHODS

Model Used

The model used in this study is the US Geological Survey's (USGS) Monthly Water Balance Model (MWBM). The MWBM has been used for decades by the USGS to study water availability around the US. It is also part of the USGS's National Hydrologic Model. We modified the original MWBM so that it can capture forest change and used the modified model in this study.

Modeling Assumptions

A key assumption in this study is that "*the past is the key to the future*". So, we used observed changes from the water balance and from vegetation after the 2013 WFC fire to generate a future fire scenario in an unburned portion of the RGH. The forest change scenario assumes that a portion of the low-elevation RGH forests will be converted from "subalpine forest" (primarily spruce-fir trees) to "mid-elevation forest" (primarily pine and other species that thrive in warmer conditions). We also assume that the "7525" (aka: "hot-and-dry") scenario published in the Technical Update to the Colorado Water Plan is most appropriate for projecting "worst-case" climate scenarios.

MODELING RESULTS

TABLE 1: SCENARIOS SUMMARIZED BY DECADE AND FLOW SEASON

		Runoff Percent-change from Baseline [%]				
	Decade	Climate Only	Forest Change + Climate	Fire 2041 Only	Fire 2041 + Climate	Fire 2031 + Climate
Average Annual Runoff Total	2021-30	-2.4	-2.4	0.0	-2.4	-2.4
	2031-40	-8.7	-8.5	0.0	-8.5	27.8
	2041-50	-14.4	-14.2	32.0	23.9	20.4
Average Melt Season Runoff Total [Apr - Jun]	2021-30	0.7	0.7	0.0	0.7	0.7
	2031-40	-3.6	-3.6	0.0	-3.6	24.4
	2041-50	-10.0	-10.0	17.1	19.9	19.3
Average Monsoon Season Runoff Total [Jul - Sept]	2021-30	-10.8	-10.8	0.0	-10.8	-10.8
	2031-40	-26.2	-26.2	0.0	-26.2	48.8
	2041-50	-38.9	-38.9	81.2	16.2	14.2
Average Low-Flow Runoff Total [Oct-Dec]	2021-30	-0.2	-0.2	0.0	-0.2	-0.2
	2031-40	1.1	1.1	0.0	1.1	46.4
	2041-50	6.0	6.0	85.8	21.0	3.7

Color Key:
< (-30) %
(-30) - (-20) %
(-20) - (-10) %
(-10) - 0 %
0%
0 - 10 %
10 - 20%
20 - 30%
> 30 %

Table 1 (left) shows changes in modeled streamflow (as runoff). Changes are shown as a percent-change from a baseline scenario. Scenarios are identified on the top row. Note: the years when wildfire simulation is initiated are shown by underlined years (e.g. 2041).

"Flow seasons" are identified on the left column, which are further broken down by each decade in the simulation period (2021-2050).

These results are further summarized in **Table 2** (below).

KEY TAKEAWAYS

TABLE 2: SUMMARY OF RESULTS BY SCENARIO

Model Scenario	Change Observed	Management Takeaways
Hot-and-dry climate scenario	• Water yield ***decreases*** throughout each annual season, except during the rising limb of annual snowmelt, when water yield increases. The rising limb is the portion of a hydrograph to the left of the peak when streamflow is rising due to spring snowmelt. Decreases in annual water yield worsen with time, as climate gets progressively hotter and drier.	• Water managers should be prepared for a ***narrower melt runoff window (earlier and faster)***. Additional attention should be placed on water conservation, water-use efficiencies, and storage to meet demands with a reduced water supply.
Wildfire scenario	• Water yield ***increases*** throughout each annual season and produces the ***greatest peak runoff*** of all scenarios. • Post-fire runoff does return to the 'baseline' condition over time as vegetation reestablishes and the watershed recovers.	• Water managers should plan for ***temporarily increased peak-runoff*** after fire. The ***timing of post-fire peak runoff likely depends on pre-fire moisture conditions***, where relatively dry pre-fire conditions may result in earlier peak runoff and relatively wet pre-fire conditions may result in delayed peak runoff.
Overlapping wildfire & hot-and-dry climate scenarios	• These scenarios also predict ***increases*** in water yield throughout each annual season and produce the highest (and ***likely earliest***) runoff of all scenarios during the rising limb of annual snowmelt. • Post-fire runoff shows gradual recovery (return to baseline condition) over time.	• Water managers should build-in ***operational flexibility*** in the timing of annual runoff collection, as the first several post-fire years will likely experience much earlier runoff under hot-and-dry climate conditions. • When forest disturbances overlap, water yield changes are often difficult to detect by observations alone. However, models allow us to estimate several water yield impacts in a more-controlled way. To best represent post-forest disturbance water budgets, ***models should be capable of representing dynamic vegetation change***.
Overlapping forest-change and hot-and-dry scenario	• Does not alter water yield relative to the 'hot-and-dry' scenario.	• This scenario changed one forest type to another forest type and was likely not drastic enough to cause changes in water yield with this model. However, if a forest type were replaced with a non-forest type (e.g., grassland) water yield changes could be apparent.

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