Blue Mesa Power Production Analysis

Web address for GitHub repository

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1 Rationale and Research Questions

Climate patterns have a significant impact on business, health, and community well-being. The western United States has been experiencing years of low precipitation and prolonged drought. Currently, all of Colorado is experiencing a moderate to extreme drought (Drought.gov). The National Oceanic and Atmospheric Administration's (NOAA) National Integrated Drought Information System (NIDIS) tracks the impacts of drought, including its effect on crops and livestock and fire. We want to explore the effects of climate patterns on hydroelectric power production, an impact that is not currently captured by NIDIS.

Hydroelectric power plants rely on a sufficient reservoir level to maintain power output, which can be an important source of carbon-free electricity. We wonder how climate patterns and reservoir management have impacted hydroelectric power production. We identified Blue Mesa Reservoir and Hydroelectric Power Plant in Colorado to explore our research questions.

Blue Mesa Power Plant has a nameplate capacity of 86.2 MW and began generating power in 1967. It is located on the Gunnison River in Colorado.

Research Questions: * Which climate and reservoir management variables influence Blue Mesa's power production? * How has electricity generation of Blue Mesa Power Plant changed over time?

2 Dataset Information

For our analysis, we relied on two data sets. For Blue Mesa's power production and reservoir management, we sourced data from the Colorado Bureau of Reclamation. The power production dataset includes monthly electricity generation reported in MWh. The reservoir management dataset includes eight variables, including elevation, storage, inflow, and outflow. We pulled monthly averages for this data from 2003 to 2021 when all the data was available.

We sourced climate data from the Colorado Climate Center, an institute at Colorado State University. We pulled monthly data for Blue Mesa on the maximum temperature, minimum temperature, average precipitation, and average snowfall.

3 Exploratory Analysis

Prior to analysis, data were explored in terms of both summary statistics and visual patterns and relationships. Table 1 summarizes the data for all fourteen variables used in building the explanatory model. Summary statistics include mean, minimum value, maximum value, and standard deviation across all observations. From 2003 to 2021, Blue Mesa Reservoir's elevation ranged from 7,438 ft to 7,519 ft. Temperature at the reservoir ranged from -11.80 °F to 87.20 °F. The Blue Mesa dam produced an average of 18,856 MWh of electricity per month with a range of 2,724 MWh to 54,068 MWh during peak production.

Variable	Mean	Min.	Max.	sd
Elevation.ft	7,486.00	7,438.00	7,519.00	18.51
Storage.af	557,251.00	247,684.00	826,302.00	134,507.54
Evaporation.af	648.60	114.00	1,544.00	443.68
Inflow.cfs	1,139.70	258.00	7,456.00	1,278.05
UnregInflow.cfs	1,137.00	195.00	7,915.00	1,366.55
Power.cfs	1,078.20	186.00	3,118.00	588.99
Bypass.cfs	58.88	0.00	2,379.00	252.86
Spillway.cfs	−11,550,000.00	−2,147,000,000.00	1,257.00	157,461,141.48
Total.cfs	1,146.30	186.00	5,939.00	761.36
MaxT	55.13	13.40	87.20	20.75
MinT	23.63	−11.80	50.80	16.76
Precip	0.73	0.00	4.39	0.61
Snow	3.91	0.00	32.90	5.86
MWH	18,856.00	2,724.00	54,068.00	10,896.96

To further explore the data, a series of graphs were developed to visually examine trends in key variables over time and well as variables with expected trends in relation to each other. In figure 1, both minimum and maximum temperatures are shown from 2003 until 2021 at Blue Mesa Reservoir. To examine trends in electricity generation over time, figure 2 plots MWh production by date (month). In the next plot, figure 3, reservoir elevation (ft) is graphed over time followed by figure 4 showing volume in acre-feet over time. Total inflow over time is then shown in figure 5.

From there, a few variables are explored graphically with respect to the dependent variable (MWh). In figure 7, total inflow (cfs) is plotted against electricity generation and shows a positive relationship. As inflow increases, electricity generation increases as well.

Power outflow is then plotted against electricity generation in figure 8, also showing a positive relationship. These trends were expected based on the high correlation between total inflow and MWh and power outflow and MWh as shown in figure 9. However, the relationships between these variables are explored further in the analysis for significance.

Last, figure 10 shows precipitation (inches) plotted against electricity generation. No noticeable trend is observed but the contribution from precipitation in explaining variation in electricity generation is explored further in the analysis.

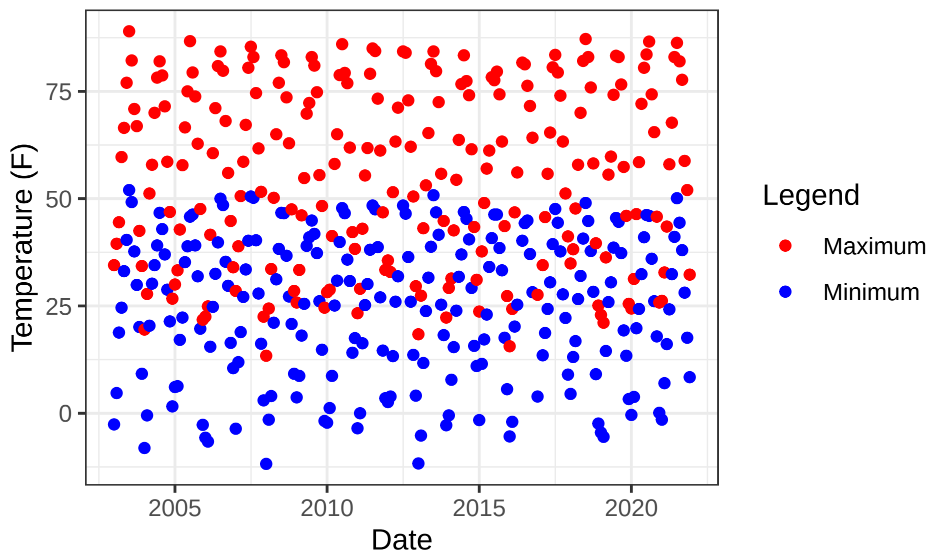

Figure 1: Minimum and maximum temperature at Blue Mesa Reservoir in Fahrenheit from January 2003 until December 2021.

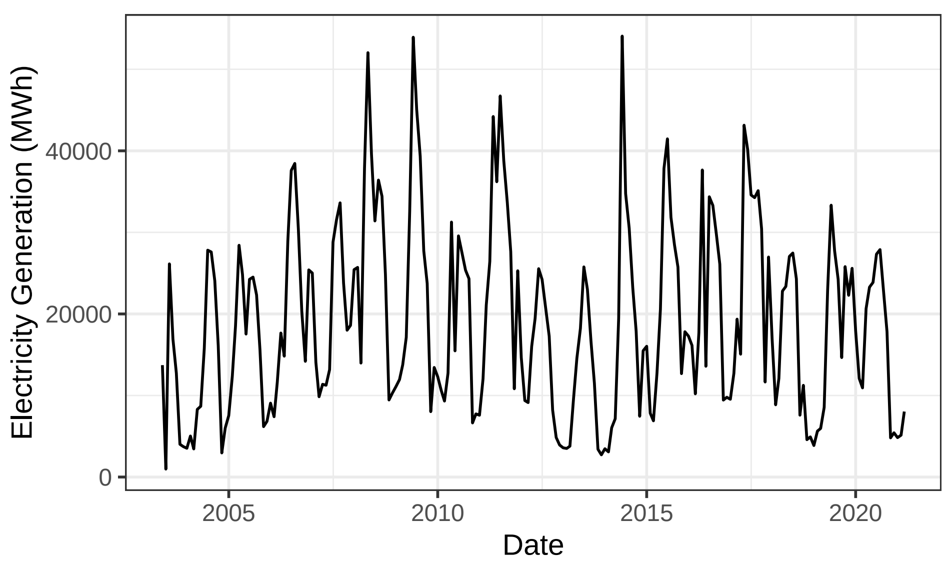

Figure 2: Power production in megawatt hours at Blue Mesa Reservoir from June 2003 until March 2021.

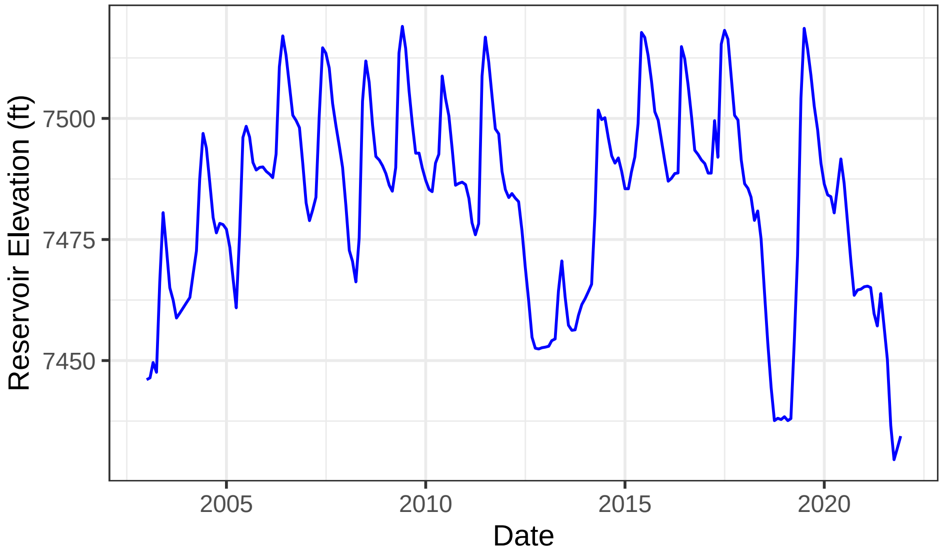

Figure 3: Reservoir elevation in feet at Blue Mesa Reservoir from January 2003 until December 2021.

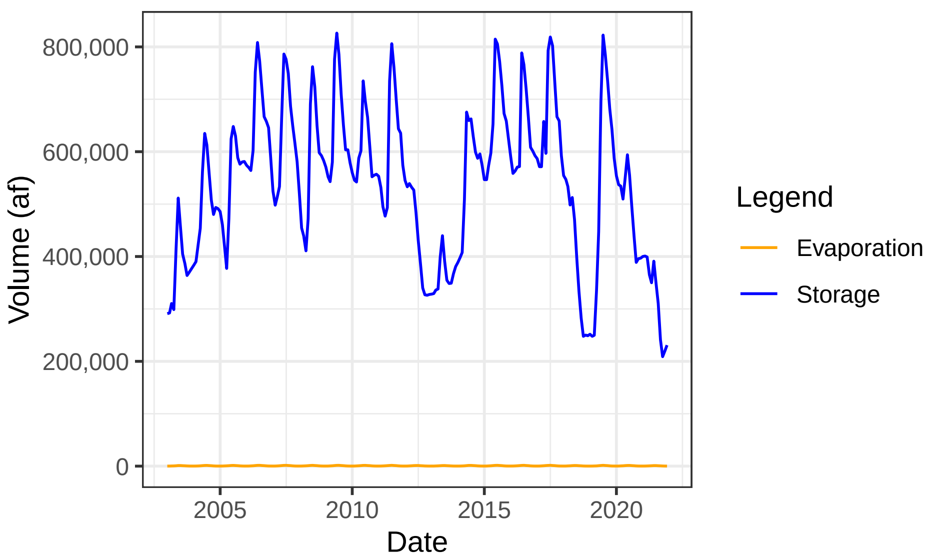

Figure 4: Reservoir volume in acre-feet at Blue Mesa Reservoir from January 2003 until December 2021.

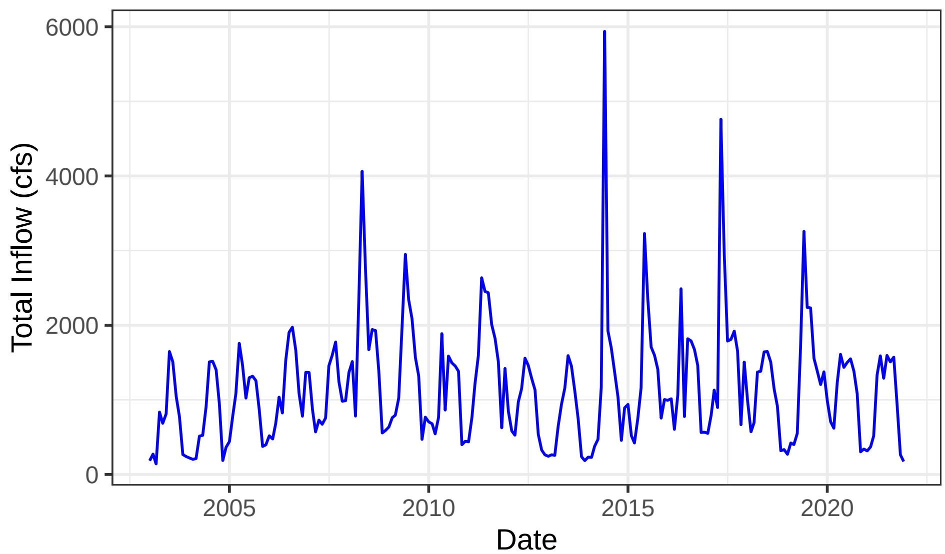

Figure 5: Total flow into Blue Mesa Reservoir in cubic feet per second from January 2003 until December 2021.

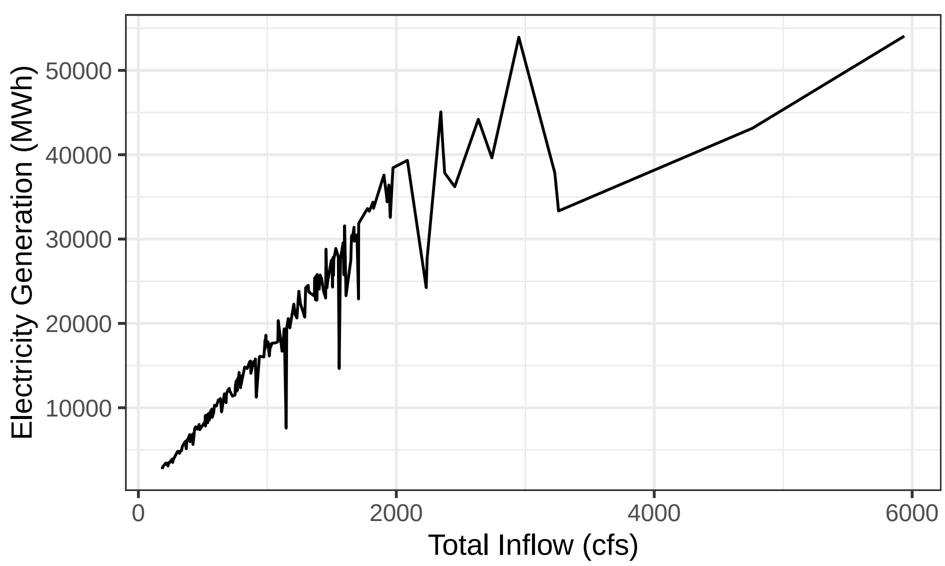

Figure 6: Relationship between total water inflow (cfs) and power production (MWH) at Blue Mesa Reservoir from 2003 until 2021.

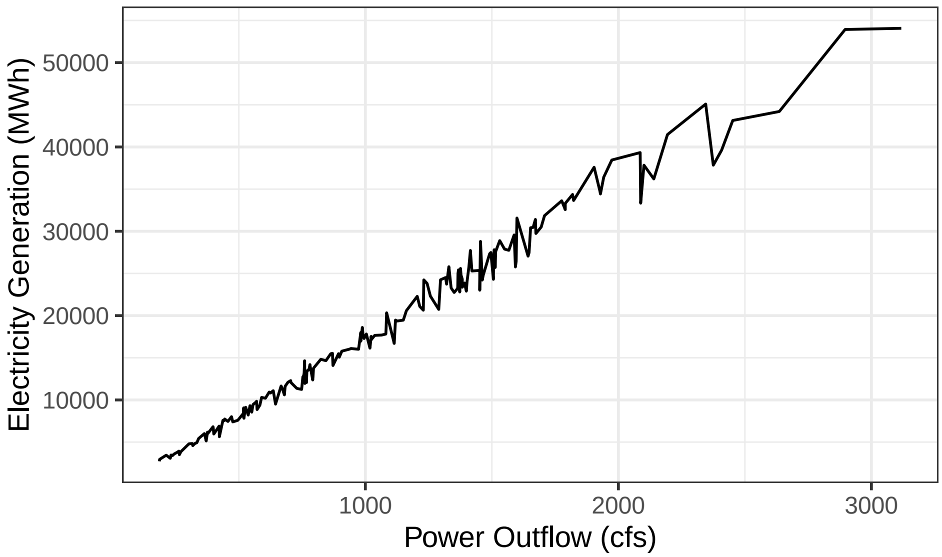

Figure 7: Relationship between power outflow (cfs) and power production (MWH) at Blue Mesa Reservoir from 2003 until 2021.

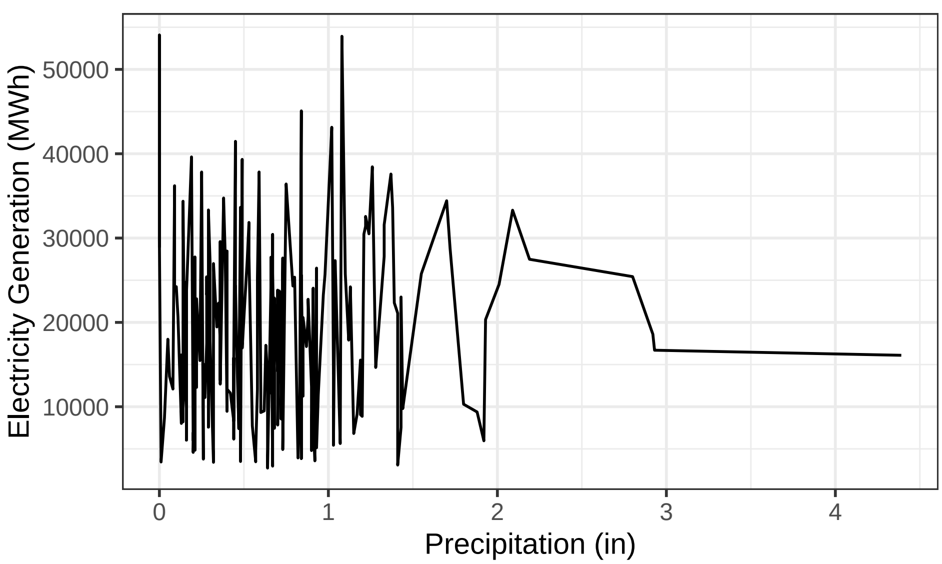

Figure 8: Relationship between precipitation (inches) and power production (MWH) at Blue Mesa Reservoir from 2003 until 2021.

4 Analysis

The analysis was divided into two components: a linear regression to explore the influene of other variables on electricity generation, and a time series analysis to explore how electricity generation has changed over time.

4.1 Question 1: Which climate and reservoir management variables influence Blue Mesa's power production?

The first step in the analysis was to explore the correlation between different varaibles used in the model. In (figure 9), narrow ovals or straight lines indicate two variables that are highly correlated. The wider the oval, the less correlated the variables are. This correlation matrix provides an understanding of how variables relate to one another and is useful when interpretting results.

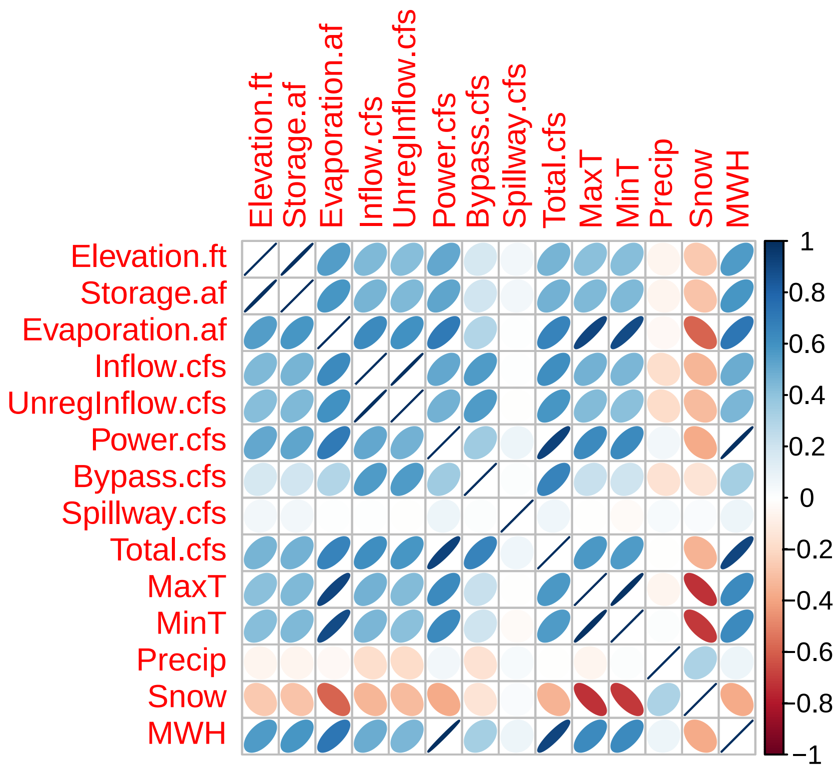

Figure 9: Correlation matrix for all dependent and independent variables used in building the explanatory model.

A multiple linear regression was then performed to explore the contribution of the thirteen independent variables in explaining variation in the dependent variable, megawatt hours (MWh). After the initial regression, an AIC test was run to identify which combination of variables contributed to the model of best fit for explaining MWh. Eight independent variables were selected for the final model and their coefficients (Beta) and significance values are summarized in Table 2.

Characteristic	Beta	95% CI[1]	p-value
Elevation.ft	-249	-322, -175	<0.001
Storage.af	0.04	0.03, 0.05	<0.001
Evaporation.af	1.4	0.54, 2.2	0.001
Inflow.cfs	-0.68	-0.82, -0.55	<0.001
MaxT	-18	-32, -4.1	0.011
Precip	166	-17, 349	0.075
Total.cfs	0.38	-0.04, 0.80	0.075
Power.cfs	17	17, 18	<0.001

[1]CI = Confidence Interval
Adjusted R squared = 1.00; AIC = 2,994

The final regression identifies elevation, storage, evaporation, inflow, maximum temperature, precipitation, total inflow, and power outflow as all contributing to explaining variation in electricity generation (MWh) across the study period. The model has an adjusted R^2 of 0.995, indicating the model explains 99.5% of the variation in MWh. According to the model results, a decrease in elevation of 249 ft per month leads to an increase of one MWh of electricity generation. This result is expected considering that as water is drawn down through the hydroelectric turbines for electricity generation, the reservoir's elevation decreases. Likewise, as power outflow increases 17 cfs, electricity generation increases by one MWh per month. This result also agrees with our expected findings since power outflow and MWh are highly correlated and since power outflow is released with the intention of generating electricity.

4.2 Question 2: How has electricity generation of Blue Mesa Power Plant changed over time?

5 Summary and Conclusions

6 References

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