

Exploring the Interactions of Climate Change, Freshwater Supply, and Environmental Balance

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Abstract. Climate change has far-reaching implications for global freshwater availability and environmental balance. The increase in greenhouse gases from the burning of fossil fuels has triggered global climate change, affecting precipitation patterns, glacier melt and sea level rise. Parts of the United States are experiencing significant changes in precipitation patterns, with some areas experiencing frequent storms and others experiencing more prolonged droughts. Accelerated glacier melt is leading to fewer water sources during the dry season, and sea level rise is threatening coastal freshwater resources, triggering saltwater intrusion and a decline in freshwater quality. Wildfires in California are an important consequence of climate change, severely affecting freshwater resources and environmental balance. Wildfires lead to reduced water resources, impacting agricultural water use and irrigation infrastructure, and affecting water quality through increased sediment and pollutant loads. The 2018 Camp Hill Fire contaminated local water sources, and the rebuilding process has increased demand for water resources, exacerbating resource constraints. Global warming has lengthened wildfire seasons and increased fire intensity, leading to increased pressure on freshwater resources. By analyzing the impacts of climate change on freshwater resources, this paper hopes to draw public attention to environmental protection and provide a reference for gradually optimizing ecosystems and creating a healthy living environment.

Keywords: Freshwater, climate change, environmental balance, wildfire.

1. Introduction

Freshwater is a key natural resource for all life forms and economic development. Increasing carbon dioxide (CO₂) emissions and greenhouse gases from activities such as burning coal, natural gas and oil are contributing to global warming. Climate change directly affects freshwater availability by influencing precipitation patterns, triggering cyclones and anticyclones, and causing climatic hazards such as droughts. At the same time, climate change-induced alterations in freshwater supply relationships seriously threaten the ecological balance [1]. Therefore, this paper takes the impacts of climate change on freshwater resources as a starting point, focusing on changes in rainfall patterns from glaciers in the Rocky Mountains to the Midwest and the impacts of sea level rise on coastal aquifers, as well as the fact that extreme climate change is causing serious freshwater management problems on a global scale. The paper also analyzes the impact of wildfires on climate change and freshwater resources, using the state of California in the United States as an example.

2. Impact of Climatic Change on Freshwater Availability

Existing studies have shown that climate change is a key factor in changes in global precipitation patterns. Changes in precipitation patterns due to climate change are occurring on a global scale. In the United States, such changes in precipitation patterns have manifested themselves in a variety of ways: some regions have experienced a significant increase in the frequency and intensity of storms, while others have experienced more prolonged droughts [2-3]. Climate change has also increased the number of rainy days in Beijing and other Asian cities, affecting freshwater resources through flooding [4-5]. China also faces significant water challenges [6]. According to the IPCC, the rate of change in precipitation patterns has intensified with an increase in extreme weather events and human activity. The IPCC report states that global warming could reach 1.5°C to 4°C, a change that further contributes to the instability of the hydrologic cycle, leading to an increase in extreme weather events.

Related studies have shown that arid regions in the southwestern United States are becoming drier, while precipitation is increasing in the northeast [7]. Thus, changes in precipitation patterns are important evidence of climate change and can negatively affect the global environmental balance.

Glaciers are an important source of fresh water in mountainous regions. As global temperatures rise, glacier melting accelerates, leading to reduced water availability during the dry season. Glacier retreat in the Rocky Mountains has been well documented, with significant reductions in mass and volume in recent decades. Reduced glacier volume affects local ecosystems as well as downstream water supplies for human communities that depend on these sources. Sea level rise due to thermal expansion of ocean waters and melting ice caps poses a significant threat to coastal freshwater resources. Sea level rise leads to saltwater intrusion and a decline in the quality and quantity of freshwater. Langevin and Zygnerski's study examines the impacts of sea level rise and saltwater intrusion on the increased salinity of groundwater resources in coastal areas, such as Florida [8].

3. Wildfire as a result of Climate Change in California

Wildfires has played a major role in impacting the freshwater concentrations of California. The above figures represent the aerial view of California in two periods. Figure 1 represents the California in 1931 and Figure 2 in 2020 [9]. From the comparison of the two images, the low vegetation cover in 2020 can be observed. This can be led by the increasing number of wildfires which are mainly caused by climate change factors.



Figure 1. California Vegetations and Inland Water Outlets of 1931 [9]



Figure 2. California Vegetations and Inland Water Outlets of 2020 [9]

3.1. Impact of Wildfires as a Climate Change Consequences

The wildfire causes reduction in water availability which has impacted on agricultural sector majorly. Irrigation use in California has been described as intensive, with the consumption

representing about 80% of the state's developed water supply. Wildfires have direct and indirect impacts on this water use [10]. Fires directly damage irrigation infrastructures while indirectly altering watersheds and depreciating water quality through increased sediment and pollutant loads in runoff [11]. Reports by the California Department of Water Resources (2021) indicate that only the 2020 wildfire season affected more than 4 million acres of land, key among them being agriculturally rich areas.

Wildfires series in California has also impact industrial and domestic water use globally as well as California. For instance, the 2018 Camp Fire that destroyed Paradise contaminated local water supplies with a toxic load due to the penetration of byproducts into the water systems from the fire itself [12]. At the same time, rebuilding after such fires seriously enhances the water demand, putting additional pressure on already scarce water resources. Climate change is relative to the increased intensity and growing incidents of wildfires in California, contributing to freshwater availability. Polade et al. address major changes in the frequency of California precipitation extremes and increasing risk of extreme weather based on the hydro climate change projections [13]. California has experienced a heightened unpredictability in precipitation patterns. The state alternates between wet and dry years, popularly known as "climate whiplash," which subjects it to a broad spectrum of extremes [14]. Such prolonged droughts, such as the one that spanned from 2012 to 2016, lead to severe water losses, diminished water levels in reservoirs, and low groundwater supplies [15]. Drought exasperates wildfire, further contributing to the loss of water resources.

Global warming has extended the wildfire season and increased fire intensity. Average temperatures in California have increased about 1.8°F since the early 20th century, according to the California Climate Assessment as reported by UCSD.EDU [16]. This rise in temperatures contributed to drier conditions and increased the area burned by wildfires [17]. Higher temperatures increase evaporation rates, reducing surface water availability and further stressing freshwater resources. Wildfires drastically change the water quality using powerfully increased runoff after fires, able to move ash, sediments, and other pollutants into diverse water flows. Besides apart from the drinks exposed to this risk, it also threatens the health of aquatic ecosystems. For instance, the 2017 Thomas Fire formed severe erosion that resulted in high contamination intensity in the water supply systems in Santa Barbara and Ventura Counties (CalFire, n.d). Looking at the Google Earth historical images, one may picture exactly how much forest cover has changed in these regions with fires, for example, Mendocino Complex Fire 2018, which burned almost 460,000 acres [18]. The loss of vegetation likewise disrupts the habitat for wildlife and, hence, leads to their displacement, which could foster extinction events. For instance, the rise of wildfires has reduced habitats for the Marbled Murrelet, a species of bird [19].

3.2. Environmental Balance

The impact of climate change on environmental balance is evident in vegetation cover changes and the increasing numbers of vulnerable species. Comparative vegetation analysis between the years, as developed from Google Earth historical imagery, reflects a considerable periodic decline in forested land and grasslands, particularly in areas prone to drought and wildfires. For instance, because of the latest wildfires in California, large forest territories have been destroyed, which has inevitably led to the violation of the balance between the local ecosystem and biodiversity. Vegetation loss not only influences carbon sequestration but also provokes soil erosion and deprives many species of habitats [11]. Further, it is estimated by the IUCN Red List that there is an increase in species turning vulnerable or getting into the endangered species list due to habitat loss and environmental changes. Species like the American Pika and Monarch Butterfly are threatened mainly by temperature increases and precipitation pattern changes affecting their natural habitats and migration patterns according to IUCN, 2022 annual report [20]. Therefore, climate change has seriously affected many species in California, driving dozens to extinction.

4. Summary

Climate change has important implications for California's freshwater supply and environmental balance. Changes in precipitation regimes, rising temperatures, and an increase in extreme weather events-particularly wildfires-have already placed significant stress on the state's water management. Prolonged droughts such as the one from 2012 to 2016 have significantly reduced water availability, impacting both groundwater and surface water. Climate change has increased the probability of wildfires. Wildfires can burn large tracts of forest and degrade water quality through increased runoff and sedimentation. Stopping this vicious cycle is not a simple matter, and it is hoped that the public will continue to raise environmental awareness and gradually optimize the ecosystem.

References

- [1] Unesco. Water for Prosperity and Peace. <https://www.unesco.org/reports/wwdr/en/2024/s>.
- [2] Shi Peijun, Song Changqing, Jing Guifei. Strengthening research on land use/cover change and its impact on ecological and environmental security in China - Trends in human-earth system dynamics research from the "Open Science Conference on Global Change" in the Netherlands. *Progress in earth sciences*, 2002, 17 (2): 161.
- [3] Chen Shouxu, Dong Yuxiang. Progress in the study of the erosive power of wind-eroded climate Chinese Desert, 2020, 40 (5): 65.
- [4] Zhang Juan. Climate change in the Northwest Arid Zone and its impact on grassland production potentials. *Ecological Science*, 2020, 39 (3): 182.
- [5] Wang Yaqin. Characteristics of wind and climate erosive force migration and influencing factors of wind erosion in Xinjiang in the last 50 years. *Geography of arid zones*, 2022, 45 (2): 370-378.
- [6] Zhang Shourong. Climate change characteristics of rainfall and number of rainy days in Bijie for 50 years. *Guizhou Weather*, 2014, 38 (A01): 5-8.
- [7] IPCC. IPCC Sixth Assessment Report. N.d. <https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-11/>.
- [8] Langevin, Christian, Michael Zygnerski. Effect of sea-level rise on salt water intrusion near a coastal well field in Southeastern Florida. *Groundwater*, 2013, 51 (5): 781-803.
- [9] California Department of Water Resources. Impacts of wildfires on water resources, 2021. <https://water.ca.gov/Programs/All-Programs/Wildfire>.
- [10] CalFire. Current Emergency Incidents Ongoing emergency responses in California, including all acre wildfires. <https://www.fire.ca.gov/incidents/>.
- [11] Proctor, Caitlin. Wildfire caused widespread drinking water distribution network contamination. *AWWA Water Science*, 2020, 2 (4): e1183.
- [12] Polade, Suraj. Precipitation in a warming world: Assessing projected hydro-climate changes in California and other Mediterranean climate regions. *Scientific reports*, 2017, 7 (1): 10783.
- [13] Swain, Daniel. Increasing precipitation volatility in twenty-first-century California. *Nature Climate Change*, 2018, 8 (5): 427-433.
- [14] Kern, Jordan, Yufei Su, et al. A retrospective study of the 2012–2016 California drought and its impacts on the power sector. *Environmental Research Letters*, 2020, 15 (9): 094008.
- [15] Ucsd, Edu. Climate Change in California. <https://scripps.ucsd.edu/research/climate-change-resources/faq-climate-change-california#:~:text=Average%20summer%20temperatures%20in%20California%20have%20risen%20by,of%20that%20increase%20occurring%20since%20the%20early%201970s>.
- [16] Bedsworth, Louise. Statewide Summary Report, California's Fourth Climate Change Assessment. Governor's Office of Planning and Research, 2018.
- [17] Schwartz, Marte. CAL Fire Management Issues Fueled, 2019. https://ctlsites.uga.edu/schwartztabithampa/wp-content/uploads/sites/1113/2020/04/Marte_Schwartz_CALFire-2.pdf.

- [18] United States Fish and Wildlife Service (USFWS). Conservation status of the Marbled Murrelet, 2019.
<https://www.fws.gov/species/marbled-murrelet-brachyramphus-marmoratus>.
- [19] IUCN. International Union for Conservation of Nature annual report, 2022.
2023<https://www.iucn.org/resources/annual-reports/iucn-2022-international-union-conservation-nature-annual-report>.