

Quantitative Methodology for Industrial Activities and Water Resources: An Analysis on Healthcare, Materials, and Consumer Discretionary Sectors and Implications for Chula Vista

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Abstract: This study investigates the relationship of industrial activities and water resources evaluation, focusing on the healthcare, materials, and consumer discretionary sectors. Utilizing the ENCORE data, I analyzed the dependencies and impacts of these sectors on water resources through 7 indicative endpoints, revealing significant variations in water usage and pollution. The healthcare sector demonstrated a critical reliance on groundwater and surface water, while the materials and consumer discretionary sectors showed similar patterns with opportunities for climate regulation. To further investigate the interactions between water resources and local socioeconomic and industrial development, I conducted a case study of Chula Vista. This analysis demonstrates how these industrial dynamics affect local communities, highlighting the socioeconomic implications of water-related challenges. The analysis leveraged spatial data, census information, and employment statistics to demonstrate how industrial activities influence water resources and community well-being. Overall, the findings from this study emphasize the need for targeted water management strategies and integration of local socioeconomic factors to resource and environmental management and sustainable practices. Policymakers and local leaders can leverage these insights to develop long-term policies that hold businesses accountable, ensuring resilient frameworks that support community success and uphold sustainable values.

Keywords: Water resources, ENCORE data, socioeconomic development, sustainability practice, case study.

1. Introduction

Water is essential for life, yet it is increasingly threatened by industrial expansion and climate change. The United Nations Sustainable Development Goals (SDGs) [1] highlight the critical need for sustainable water management, with SDG 6 aiming to ensure the availability and sustainable management of water and sanitation for all. Despite these efforts, water scarcity affects nearly half of the world's population for at least part of the year, with over 2 billion people lacking access to safe drinking water [2].

Industries such as healthcare, manufacturing, and consumer goods are major contributors to water stress, consuming vast amounts of water and often leading to pollution and depletion of resources.

The healthcare sector, for example, requires significant water for sanitation and patient care, while manufacturing processes can introduce pollutants into water systems. These activities exacerbate water scarcity and degrade water quality, posing risks to both biodiversity and human health.

The socioeconomic implications of water scarcity are profound. Increased operational costs due to water scarcity and contamination can affect employment and economic stability, particularly in communities reliant on water-intensive industries. According to the UN World Water Development Report, water demand from the municipal sector has experienced a considerable increase relative to other sectors. As water becomes a contested resource, the need for sustainable practices and policies becomes more urgent. This research delves into the dependencies of key sectors on water resources, utilizing ENCORE data to identify potential risks and opportunities.

Recent studies leveraging the ENCORE biodiversity module have offered significant insights into how financial activities and specific sectors, such as mining and agriculture, interact with biodiversity risks and sustainability goals. These studies have effectively mapped the impacts of financial portfolios on species extinction risks and ecological integrity, helping to guide sustainable investment strategies in high-priority areas. Addison et al. [3] have examined corporate biodiversity performance using ratings and metrics, while other prominent approaches include assessing ecosystem services dependencies, evaluating supply chain impacts, and quantifying biodiversity footprints. Additionally, research focused on the agriculture sector has underscored the importance of integrating biodiversity considerations into corporate practices to mitigate risks and achieve global conservation goals [4]. While this body of work has contributed to our understanding of biodiversity risks, it has not specifically addressed the critical issue of water resources or how industrial activities affect water availability, quality, and related socioeconomic outcomes.

My research seeks to bridge this gap by focusing specifically on the intersection of water resources, industrial influences, and their socioeconomic impacts. Unlike existing studies that have treated biodiversity and water management as separate concerns, recent research has highlighted the need for an integrated approach. For instance, Konica Minolta [5], a Japanese multinational technology company, has implemented comprehensive guidelines for biodiversity preservation and water resource management in their production activities, demonstrating how industrial processes can be adapted to consider both aspects simultaneously. Their Green Factory Certification System evaluates environmental activities at production sites, including water intake reduction targets and measures to prevent ecological damage from wastewater emissions.

Furthermore, Martín Muñoz et al. [6] emphasized the importance of integrating well-designed Aqua-Nature-based Solutions (aNBS) into urban planning to enhance both biodiversity and resilience to water-related climate hazards. Their study of urban water bodies functioning as aNBS showed that these systems can support high plant biodiversity, particularly in temporary ponds, while also providing water regulating ecosystem services such as enhanced infiltration and groundwater recharge.

The interconnectedness of water resources, biodiversity, and socioeconomic factors is further underscored by *the Convention on Biological Diversity's report on Water and Biodiversity*. This report highlights how well-functioning ecosystems provide services that influence water availability and quality, which in turn affect water management goals such as water storage, flow regulation, and flood protection. These ecosystem services are directly impacted by water and land management decisions, creating a feedback loop that influences both biodiversity and socioeconomic outcomes.

To better understand the impacts and dependencies among water, biodiversity, and socioeconomics, I compared the biodiversity and socioeconomic metrics related to three distinct sectors: Healthcare, Materials, and Consumer Discretionary. In addition, I took a detailed case study on water-related metrics in my hometown, Chula Vista, where these three sectors are the main

industrial activities with most employment. In the case study, I also focus on how these changes, in turn, affect local communities.

The case study of Chula Vista is particularly important as it provides insights into the water-industry nexus in a rapidly growing urban area with a diverse economic base. Economically, Chula Vista has a mixed socio-economic profile, with both affluent neighborhoods and areas facing economic challenges. Its economy is supported by a range of industries, including healthcare, education, and retail, with significant growth in residential and commercial developments in recent years. This rapid development has put considerable pressure on local natural resources, particularly water, making Chula Vista an ideal location for examining the impacts of industrial activities on water resources.

Unlike previous studies that have focused on single industries or broader regional analyses, this research contrasts the relationship with water of three key sectors in Chula Vista: Healthcare, Materials, and Consumer Discretionary. These sectors, which include major employers like Sharp Chula Vista Medical Center, Rohr Inc./Goodrich Aerospace, and retail giants such as Walmart and Costco, represent a significant portion of the city's industrial activities and employment. By combining the ENCORE database's quantitative metrics with spatial data and census information on Chula Vista's population, this study provides a unique perspective on how these industries impact local water resources and biodiversity. This work adds several new dimensions to the community's understanding of environmental sustainability:

- It provides a sector-specific analysis of water-related impacts in Chula Vista, offering actionable insights for local policymakers and industry leaders, including major employers like Sharp Healthcare and Southwestern College.
- By incorporating spatial data and demographic information, it highlights potential environmental justice issues related to water resource management and industrial activities across Chula Vista's diverse neighborhoods.
- The study establishes a replicable framework for other municipalities to assess and manage their industrial-water-socioeconomic nexus, potentially informing more sustainable urban development strategies.
- It bridges the gap between theoretical frameworks and practical, community-level implications, demonstrating how global tools like ENCORE can be applied to Chula Vista's specific context for tangible benefits.

Leveraging the ENCORE database enables quantification of the impacts and dependencies of industry processes on water-related biodiversity metrics, such as the extent of water resource depletion and contamination linked to specific industrial activities. This data offers valuable insights for policymakers and industry stakeholders on mitigating adverse impacts and promoting sustainable practices.

This work advances the limitations of existing research but also provides a comprehensive framework and holistic understanding of environmental sustainability and its socio-economic dimensions, particularly in the context of industrial influences on water resources.

2. Methodology

The data for this research was sourced from the leading ENCORE (Exploring Natural Capital Opportunities, Risks, and Exposure, <https://www.encorenature.org/en>) [7] biodiversity database, which provides comprehensive insights into the dependencies and impacts of various economic sectors on natural capital, including water resources. Using ENCORE's methodology, which categorizes dependencies and impacts into various risk levels, I systematically examined the existing sectors and their sub-industries.

I selected 3 industries: Healthcare, Materials, and Consumer Discretionary for our analysis due to their significant and varied impacts on daily life and economic structures. The healthcare and

consumer discretionary sectors directly influence individuals' well-being and lifestyle, making them critical for assessing water dependency and its societal implications. In contrast, the materials sector, though more industrial and mechanized, provides a comprehensive view of water use across broader economic activities. This selection ensures a diverse and representative analysis of water dependency across different types of industries, highlighting the breadth of water usage and its effects on both personal and industrial scales.

For each sub-industry, I collected the dependency levels for water-related items. These include groundwater, surface water, water flow maintenance, water quality, climate regulation, dilution by atmosphere and ecosystems, and mediation of sensory impacts. ENCORE has rated the dependency levels one of the following: very low, low, medium, high, or very high. These categories were then assigned numerical values from 1 (very low) to 5 (very high) to transform to ordinal data.

The transformed dependency levels were compiled into a structured dataset, converting qualitative ratings into numerical values for statistical analysis. Using this quantified data, for each industry above, I calculated the average score for each ecosystem service that encompasses the processes that involve natural resources/capital as well as the frequency of the dependencies by each endpoint.

To add more tangible and in-depth information, I included a case study on natural capital depletion in regions in Southern California. In Chula Vista, a city located in Southern California's San Diego County. Chula Vista, meaning "beautiful view" in Spanish, is the second-largest city in the county and one of the fastest-growing cities in the region. The population of Chula Vista exceeds 275,000 and has a diverse demographic composition.

I also collected and analyzed the spatial data for Chula Vista and its peripheral regions from the ENCORE (Exploring Natural Capital Opportunities, Risks, and Exposure) database (<https://www.encorenature.org/en/explore>). I selected specific data layers relevant to our study: Baseline Water Stress, Ocean Pollution, Surface Water Drought Severity, and Water Quality Variability in Water Supply.

'Baseline Water Stress,' which measures the ratio of total water withdrawals to available renewable water supplies data helped us assess regions with high water demand relative to supply [8]. 'Ocean Pollution,' or the introduction of substances or energy from humans into the ocean that harm the environment, living resources, and human health, data provides insights into changes in pollution levels from 2008 to 2013 [9]. 'Surface Water Drought Severity' Data, which looked at a severe moisture deficit of surface level water below expected levels that restricts activities in months of dryness from 1901 to 2008, highlighted areas prone to drought. 'Water Quality Variability' measures annual variation in water supply, indicating regions with inconsistent water availability [10].

The above metrics were overlaid on maps of the study area to visualize and analyze location-specific risks, dependencies, and impacts of business activities on natural capital. In addition, I obtained employment data from data published by the US government data from the census bureau and the compiled Data USA database [11], composed of thousands of official governmental sources for specific employment breakdowns by industry/sector as well as overall population overviews.

3. Results and discussion

3.1. Analysis of impact scores for three selected sectors

The ENCORE data provides a detailed analysis of the impact scores for the healthcare, materials, and consumer discretionary sectors, highlighting their dependencies on water resources and their contributions to water-related challenges.

Healthcare Sector

The healthcare sector exhibits the highest dependency score in climate regulation, yet only 2 observations were reported. However, the sector's reliance on groundwater and surface water is

critical, with scores of 3 and 4 out of 5, based on 14 observations for each. This underscores the substantial water usage required for sanitation, patient care, and facility maintenance. The sector's impact on water resources is compounded by the disposal of pharmaceuticals and chemical wastes, which can introduce contaminants into local waterways. These dependencies highlight the sector's vulnerability to water scarcity and emphasize the need for efficient water management practices. In addition, water flow management receives a score of 3, further stressing the importance of water management.

Materials Sector

The materials sector demonstrates significant reliance on groundwater and surface water, both scoring 3.5 with a reported count of around 28. This high dependency reflects the sector's need for substantial water resources in manufacturing processes. The sector's impact on water resources is further exacerbated by industrial activities that contribute to pollution, such as waste management facilities that may lead to leachate entering water systems. The materials sector's water dependencies indicate potential risks related to water scarcity and pollution, necessitating targeted strategies to mitigate these impacts.

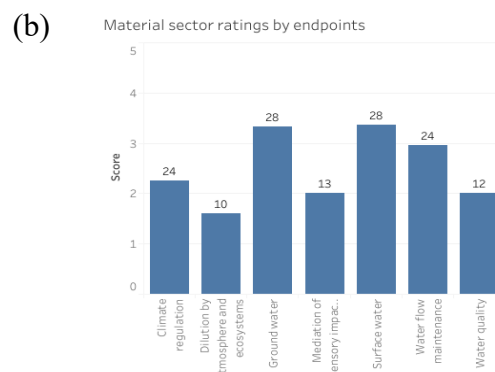
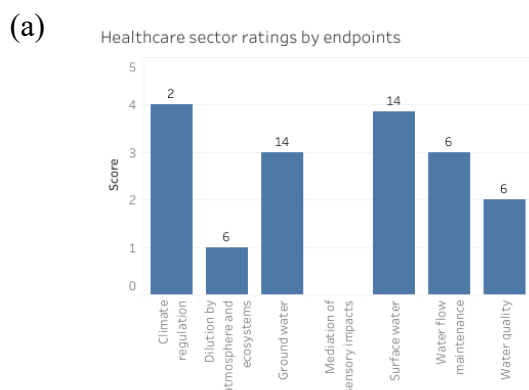
Consumer Discretionary Sector

The consumer discretionary sector shows a similar pattern to the materials sector, with groundwater and surface water scores of around 3.5, respectively. Similar with the Material sector, the dependency on climate regulation suggests opportunities for implementing sustainable practices that align with environmental goals. The consumer discretionary sector's dependencies highlight the sensitivity of water use to climate considerations, indicating solid demand-side opportunities for co-managing water use and climate impacts.

Comparative Analysis and Insights

The visual representation of the ENCORE data reveals distinct patterns and trends, allowing for the identification of industries with the highest and lowest dependencies on water resources. The healthcare sector's unique profile, with minimal dependencies on mediation of sensory impacts and dilution, contrasts with the more water-reliant materials and consumer discretionary sectors. This comparative analysis provides insights into potential areas of risk and opportunity, enabling stakeholders to manage water-related risks effectively and make informed decisions.

The economic implications of these water dependencies are significant. The healthcare sector, a major employer, faces challenges related to water scarcity and contamination, which can lead to higher operational costs and impact community health. The materials and consumer discretionary sectors, while also significant employers, are more vulnerable to water supply variability, affecting their long-term sustainability and economic contributions.



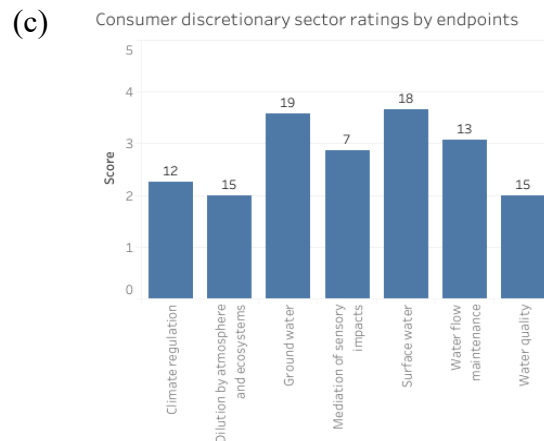


Figure 1: Impact ratings by endpoints from ENCORE for (a) the healthcare, (b) material, and (c) consumer discretionary sectors. The bars show the “Score” as the average rating for each endpoint, and numbers on top of the bar show the number of ratings available in ENCORE used to calculate the average score.

3.2. Case Study

Chula Vista, a city located in the South Bay region of San Diego County, is experiencing rapid growth and industrial development. This growth, while economically beneficial, poses significant challenges to water resource management, including high baseline water stress, ocean pollution, and variability in water supply. Zooming in to Chula Vista in the ENCORE database (<https://encorenature.org/en/map?id=11>), I identified the below water-related issues based on Figure 2:

High Baseline Water Stress

Chula Vista's urban expansion and residential development have driven a substantial increase in water demand, contributing to high baseline water stress. The city's development plans show extensive residential growth, which, alongside water-intensive businesses such as hotels and restaurants, exacerbates local water consumption. According to the San Diego County Water Authority (SDCWA), commercial activities significantly contribute to this demand, necessitating strategic water management to support the growing population.

Ocean Pollution

The Port of San Diego and associated shipping activities are major sources of ocean pollution in the region. These activities introduce pollutants such as ballast water discharge, oil spills, and emissions into the coastal environment. The Port of San Diego's Environmental Protection Program outlines the impacts of these activities on coastal water quality. Additionally, recreational boating and beach tourism contribute to pollution through fuel spills and littering, despite efforts by organizations like the Surfrider Foundation to mitigate these impacts through regular cleanups.

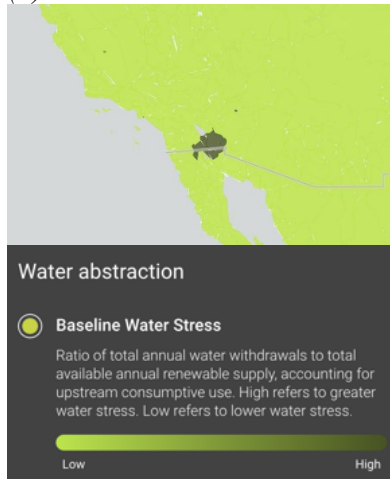
Industrial manufacturing also contributes to ocean pollution. Waste management facilities in San Diego County, if improperly managed, can lead to leachate entering the water system, eventually reaching the ocean. Cross-border pollution from the Tijuana River Valley further exacerbates the situation, as sewage and industrial waste from Mexico flow into Chula Vista's waterways, affecting water quality and marine life.

Variability in Water Supply

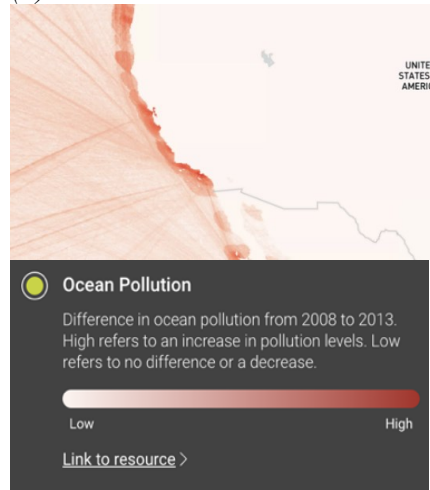
Chula Vista's water supply variability is influenced by its reliance on imported water from the Colorado River and Northern California, which are subject to droughts and regulatory constraints. This dependence creates fluctuations in water availability, impacting sectors like energy production,

where hydropower output is affected by water scarcity. The healthcare industry, a significant water consumer, also faces challenges in maintaining operations during periods of limited supply [12]

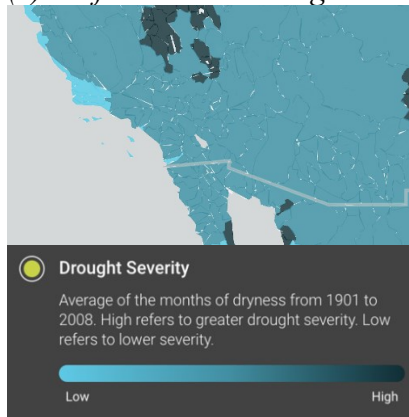
(a) *Baseline Water Stress*



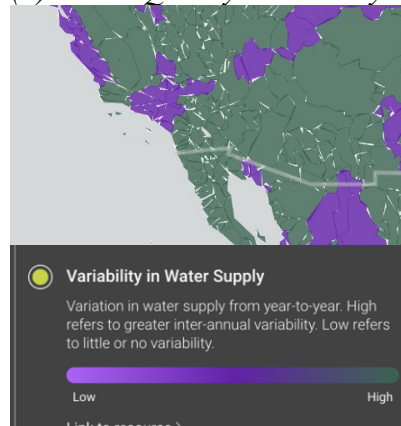
(b) *Ocean Pollution*



(c) *Surface Water Drought Severity*



(d) *Water Quality Variability in Water Supply*



(e) *Water pollutant data*

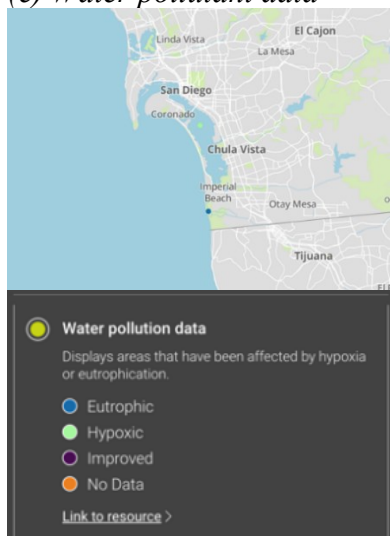


Figure 2: Geospatial data for the Chula Vista region for (a) Baseline Water Stress, (b) Ocean Pollution, (c) Surface Water Drought Severity, (d) Water Quality Variability in Water Supply, and (e) water pollutant data.

Key sectors in Chula Vista include Health Care & Social Assistance (15.40%), Retail Trade (11.40%), and Public Administration (8.44%), reflecting their significant roles in the local economy. The percentage represents the population employed across various industries, as shown in Figure 3.

The healthcare sector in Chula Vista is a major water consumer, with facilities such as Sharp Chula Vista Medical Center requiring substantial water for sanitation, patient care, and facility maintenance. The disposal of pharmaceuticals and chemical wastes poses additional challenges, as these contaminants can enter local waterways and affect aquatic ecosystems and human health. Efforts to implement water-efficient technologies and comply with regulatory guidelines are underway, but the effectiveness varies across facilities.

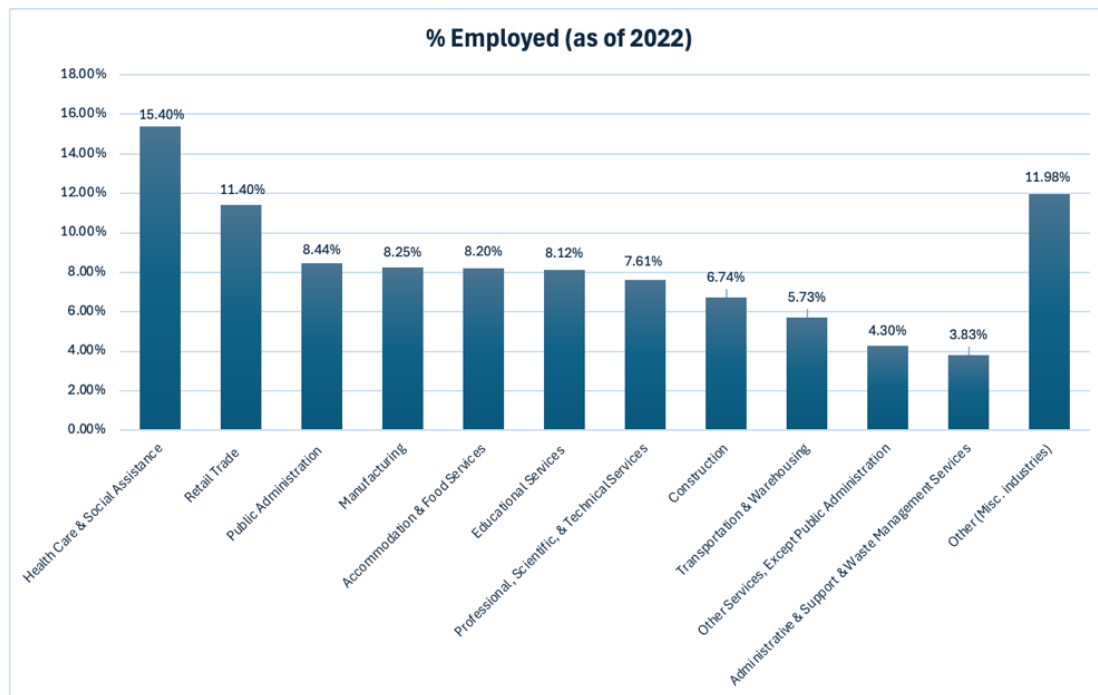


Figure 3: Employment Distribution in Chula Vista by sector for 2022

Socioeconomic Implications

Chula Vista's economy is supported by a diverse range of industries, with office and administrative support occupations being the most common job group, employing over 15,000 residents. The healthcare and manufacturing sectors are also significant employers, with companies like Rohr Inc./Goodrich Aerospace contributing to the local economy. However, these industries are major consumers of water resources, highlighting the need for sustainable practices to ensure long-term economic stability.

The city's median household income has grown significantly, reaching \$101,984 in 2022, reflecting economic development across various sectors (Data USA, 2022). However, the high cost of water and the need for advanced water treatment technologies increase operational expenses for healthcare facilities, potentially leading to higher healthcare costs for residents. Water scarcity can also limit the expansion of healthcare services, affecting access to medical care, particularly for vulnerable populations.

The city is predominantly Hispanic or Latino, accounting for over 60% of the population, followed by White (non-Hispanic), Asian, and African American communities. This diverse ethnic makeup reflects the city's rich cultural heritage and vibrant community life. However, to our knowledge, there have been few analyses on the distribution of water-related impacts across the community. Water scarcity and contamination directly affect community health, particularly for vulnerable populations.

Ensuring a reliable and clean water supply is crucial for maintaining public health standards in healthcare settings. The socioeconomic factors, including income disparities and employment in water-intensive industries, contribute to the community's ability to withstand environmental hazards and climate change.

The relationship between different industries and water-related impacts in Chula Vista is complex. Agriculture, residential and commercial development, port activities, industrial manufacturing, tourism, and water management practices all contribute to high baseline water stress, ocean pollution, and variability in water supply. Addressing these issues requires coordinated efforts across sectors, including adopting sustainable practices, improving pollution controls, and enhancing water management strategies to ensure a resilient water future for Chula Vista. By providing a comprehensive understanding of these dynamics, this case study offers valuable insights for policymakers and industry leaders to ensure a resilient and sustainable water future for Chula Vista.

The research is particularly relevant given Chula Vista's commitment to sustainable development, as evidenced by its industrial zoning regulations that aim to ensure the purity of air and water while protecting nearby residential and commercial areas.

4. Conclusion

This study systematically examined the dependencies of the healthcare, materials, and consumer discretionary sectors on water resources, utilizing ENCORE data to identify specific risks and opportunities. By analyzing these sectors, I found significant variations in water dependency, with the healthcare sector showing critical reliance on groundwater and surface water, while the materials and consumer discretionary sectors exhibited similar patterns but with distinct opportunities for climate regulation.

The results highlight the urgent need for targeted water management strategies tailored to each sector's unique dependencies. The healthcare sector's vulnerability to water scarcity and contamination underscores the necessity for efficient water management practices. Meanwhile, the materials and consumer discretionary sectors present opportunities for sustainable practices and exploring alternatives that align with climate goals.

To investigate the interactions between water management strategies and socioeconomic development, I dived into the case study on Chula Vista. I analyzed the interactions between key employment industries, water resources, and socioeconomic factors, emphasizing how these dynamics align with the local community. By integrating spatial data, census information, and employment statistics [13], this analysis provides insights into sustainable management practices.

In summary, by leveraging the ENCORE data and considering socioeconomic factors, policymakers and industry leaders can make informed decisions to promote sustainable practices and ensure a resilient water future. In this paper, this comprehensive approach is shown to effectively decompose the complex water-related challenges entangled with socioeconomic distributions and industrial development in local communities.

In the long run, it is imperative to hold businesses accountable and adopt long-term sustainable policies to ensure long-lasting frameworks that set up communities for success.

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