A Study of Water Supply and Demand Dynamics in Danao City, Cebu, Philippines

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Abstract
Water demand and supply dynamics are critical to understanding the sustainability of our water resources in the face of growing population pressures and economic development. As the global population expands and industrial activities increase, the demand for freshwater has surged, placing unprecedented strain on available supplies. Balancing the complex interplay between water demand and supply is essential to ensure that this vital resource can meet current needs without compromising the ability of future generations to access it. The study investigated water demand and supply in Danao City, Cebu, Philippines. The research utilizes data from government agencies and the Danao City Water Works System (DCWWS) to assess their influence on water consumption by examining factors like population growth, economic activity, and environmental conditions. The study recommended solutions like infrastructure improvements, water conservation programs, and exploring alternative water sources to ensure a sustainable water future for Danao City. Despite rising demand linked to population growth, models predict Danao City's water supply will increase in the coming years to accommodate the entire Danao City and other neighbor places as well. The study suggests that Danao city can meet demand considering the number of households, temperature, and Precipitation; the water supply exceeds the projected water demand by 26%-27% of water supply over the next five years and beyond.

Keywords: water cycle, urbanization, economic development

CHAPTER 1: INTRODUCTION

Freshwater, a seemingly abundant resource, is vital for all life on Earth. Yet, its availability is not uniform, and the balance between water supply and demand is becoming increasingly precarious. The study focuses on the complexities of water resource management, examining the factors influencing freshwater availability and the ever-growing human demand for this essential resource.

The study is anchored on Turton and Ohlsson's hydro-social contract theory (HSCT) (2018) at the 9th Stockholm Water Symposium, where all stakeholders have a voice in decision-making. This theory postulates that several transitions occur in society concerning the development of water resources and that these transitions can lead to many social instabilities. Let us assume there was initial water abundance in a given geographical entity at some past moment. Then, the water demand increased with the population expulsion and the rapidly changing technology. The initial water abundance gave way to a prevailing condition of water scarcity.

The 6th Sustainable Development Goal 2018, published by the United Nations, is to "Ensure access to water and sanitation for all." This part of the report emphasizes the importance of investing in the water and sanitation sector to improve water resource efficiency and ensure safe access to water sources for the population. In the Philippines, beyond 101 million Filipinos, there are nine million who rely on unimproved, unreliable, and unsustainable water sources (water.org, 2019). According to the United Nations (2018), the statement Water for a Sustainable World was based on the concern of water resources in world regions in the context of three key dimensions of sustainable development - poverty and social equity, economic development, and ecosystems. This report illustrated the importance and the priority of rational use of water resources; thus, these resources are the basis for sustainable urban and rural development.

Social Equity: Access to secure drinking water and sanitation is a human right. Yet, its limited understanding worldwide often has unequal impacts on people with low incomes, women, and children (UNESCO, 2021).

Mogelgaard (2018) states that population development significantly contributes to water scarcity. Growth in populations means escalating demand and rivalry for water for local uses. As projected by United Nations Population Division (2021), due to population growth by 2035, 3.6 billion people will reside in regions experiencing water scarcity, leading to more countries and areas facing water shortages. The path of future population development will impact water tension and shortage. This path will mostly depend on the family's choices in terms of the future.

Salem's (2022) research revealed that household demand for water increases with household number and size. Other factors, especially the price of water, have no significant impact on the water demand. As the risk of non-revocable change in the number of precipitation patterns increases with climate change, so do the populations traditionally rely on the natural water cycle. Therefore, it is crucial to explore the potential for migration in light of the current water crisis, which has ranked among the five most impactful global risks for the fifth consecutive year.

Economic Development: Water is one of the most profoundly critical natural resources involved in the economy. Because the volume of annual water usage far surpasses the mass of all the primary extracted resources (Bobyleva & Grigor'yeva, 2018). The water demand was categorized by the U.S. Geological Survey Circular 1344 (2019) as follows: 40.9 percent from Thermoelectric Power, 36.6 percent from irrigation, 12.7 percent from a public supply, 4.9 percent from industrial use, 2.5 percent from aquaculture, and 2.4 percent from domestic, livestock, and mining. Hurt, Anda & Ho (2021) cited the primary categories of water needed by residential households, such as for drinking, cooking, washing, bathing, laundry, toilet flushing, home cleaning, and home maintenance. The categories mentioned generally cover the primary types of water households need in their daily activities. Not all classes can be applied to all households, and different households may require different water categories.

According to the World Health Organization (WHO), a minimum of 50 liters per capita and day (LCD) is required to acquire the consumption needs and assure hygiene (Howard and Bartram, 2023). Gleick (2018) stated that, on average, 5 liters per day are needed for drinking water, 10 for food preparation, and 35 for bathing and sanitation services. Thus, water is a limited and fragile resource, crucial for supporting life, development, and the environment. It has an economic value in all its competing uses and should be recognized as an economic good.

Water consumption predictions and management should reasonably fulfill the rigid demand of water users and control unreasonable demand based on water consumers' demand to properly match water resources with the state of socioeconomic development (Pan et al. 2018).

The distribution of water services for the population is the most critical factor contributing to sustainable development and improving living standards. Maintaining this industry at the highest quality is essential to ensuring uninterrupted access to water services. Timely equipment repair, technical refurbishment of production, reconstruction, and modernization of wastewater treatment plants are also necessary.

According to Measure Evaluation (2018), the weaker the data quality and the longer the projection period, the less reliable the results are. Twenty-year projections are less reliable than those of 5-10 years. Also, economic happenings can influence in- or out-migration and lead to prompt growth. The environment also influenced the population change. For example, droughts and floods can significantly reduce population size.

According to Population. City (2019), an administrative unit of Danao City, Cebu, Philippines, last known population is close to 136 500 (the year 2019). This was 0.136% of the total population. Danao population in 2019 would be 151,000 if the population growth rate were the same as in 2000-2019 (2.31%/year).

According to EPA (2021), the water cycle is a delicate balance of Precipitation, evaporation, and all the steps. Warmer temperatures escalate the water's evaporation rate into the atmosphere, increasing the atmosphere's capability to hold water. Temperature affects the volume of rain or Precipitation. Thus, the temperature does not directly relate to the water supply. Rapid changes in the amount of rain falling during storms prove that the water cycle is already shifting. As temperatures increase, people and animals need more water to uphold their health and prosper. Many essential economic activities, from powering our cities to raising animals and growing crops, rely heavily on water. These will increase the water demand for each activity.

However, nowadays, the importance of water supply services needs to be recognized, which often creates an imbalance in water use and harms natural habitats. This also happened in the water supply of Danao City, wherein the water supply was scheduled. Some parts of the city had a water supply only in the morning; others had it in the evening.

The different water sources are groundwaters from springs, rivers, deep wells, lakes, ponds, canals, and other sources. In Danao, water comes from springs, rivers, and deep wells. According to the Philippines Environment Monitor (2023), there are 145,990 groundwater and surface water potential in the Philippines. Part of it is from Central Visayas (Region VIl), with 2,939 potential water resources. The constant supply of these water sources depends mainly on the rainfall. It will also depend the dimensions of the watershed, the steepness of the terrain, the composition of the soil, the types of plants present, and the human activities on the land.

Environmental Protection and Ecosystem Services: The environment plays a major role in shaping how much water is available decrease demand (Lankford, 2023). Precipitation increases, or evapotranspiration, will likely expand water supplies and lessen the water demanded by irrigated agriculture. Temperature increases or decreases in stagnated areas or biological diversity are likely to reduce the availability of supplies and improve the water demand in many water-using sectors. Global change will likely profoundly impact regional water supplies and demands. But the understanding of people on global climate patterns makes it challenging to pinpoint regional impacts. forecast how critical variables such as temperature and Precipitation might change in the study area. For example, a forecasted 1.0 C increase in 2020 in a provincial area means that 1.0 C is added to the province's baseline mean temperature value, as shown in the table, to reach the value of the projected mean temperature. In a similar method, for, say, a +25%-rainfall change in a province means that 25% of the seasonal mean precipitation value in the said provincial area (from the table of baseline climate) is added to the mean value.

Being located in the Ring of Fire, the Philippines is prone to an abundant water resource. It has been identified that there is an average annual rainfall of about 2,500 millimeters (Barba, 2022). Based on the latest assessment, the dependable supply is projected at about 126,000 million cubic meters per year (MCM/year).

Chang et al. (2019) said there is a relationship between weather and climate variables and seasonal water consumption. Water use tends to be higher in early summer than later summer. This could be because of factors other than just temperature, like humidity and how much water evaporates. Since rain and evaporation affect how much moisture is in the soil, it's important to consider this when predicting water needs, especially for lawns, gardens, pools, and car washing.

The criteria for the three influential factors are as follows: social factors (population growth, number of households), economic factors (water supply and demand), and environmental factors (water pollution, weathered seasoned variations in terms of temperature and precipitation level).

As reported by Greenpeace (2022), the problems concerning water use and scarcity were due to disparities between water supply and demand, a lack of a water allocation formula, corporations directly competing with the people for the control and use of available freshwater resources, weak water use regulation and enforcement, inefficient water use, depletion of groundwater resources, fragmented management, and climate change.

Linear regression models are essential for identifying the problem between water supply, water consumption, and population growth. Completing a linear model this doesn't happen in just one step. It's a series of steps that require careful examination of each item involved. When creating linear models, the most important factors can vary based on what you want to predict and the field the researchers working in.; these include obtaining acceptable parameter estimates and a good model while meeting standard statistical model assumptions. The main advantages of linear models are interpretability and prediction (Bates and Watts, 2018).

Understanding the delicate balance between water supply and demand is crucial. Ensuring accessibility and adequate water and sanitation administration is a critical priority for sustainable growth. A growing population and seasonal weather variations all contribute to rising water demand. This gap between what we need and what we have is the core challenge addressed in Water Demand and Supply at Danao City. By analyzing these factors, we can develop sustainable solutions for managing this irreplaceable resource for the future.

CHAPTER 2: REVIEW OF LITERATURE

1. Previous study investigates how social behavior influences water use in Brazilian households. Researchers examined water consumption data alongside social connections between households. They found that people tend to consume water similar to their neighbors. Interestingly, high water users influenced those around them more than the reverse. Encouraging water-saving behaviors as the norm can lead to a reduction in water demand. People might adjust their water use based on what they perceive as normal behavior within their social circles. This highlights the potential for social pressure to promote water conservation efforts if water-conscious households become the majority. Martínez, D. M., & Maia, A. G (2021)
2. Drawing upon the Analysis of Water Supply-Demand Based on Socioeconomic factors, the researchers developed a model considering population growth alongside economic development and

water-saving practices. Their model suggests that economic growth is a significant driver of water demand. Due to industrial activity and lifestyle changes, water consumption typically increases as economies develop. However, the study also found that water-saving initiatives can significantly reduce pressure on the water supply. This emphasizes the importance of promoting water conservation alongside economic development to ensure water security. Jianjun et al. (2022)

3. Numerous studies such as Social Capital and Water Conservation: A Review of the Literature
4. analyzes the connection between social capital (trust and cooperation within communities) and water conservation efforts. The authors examined research on how social networks and community dynamics influence water use. They suggest that strong social networks can promote water-saving behaviors. When people trust and cooperate, they are more likely to share information about water conservation practices and hold each other accountable for sustainable water use. The review also highlights the potential for community-based water management initiatives to leverage social capital for collective action in addressing water scarcity. Singha, B., & Eljamal, O. (2020)
5. Analyzing household water demand in urban areas examines water consumption patterns in Faisalabad, Pakistan. Analyzing data from 1100 households, it finds a positive correlation between household size and water use. The research highlights the limitations of price-based water conservation strategies in developing countries, suggesting alternative approaches like public awareness campaigns. Narmilan (2020)
6. Socioeconomic factors influence households' water demand function in Jordan. Focusing on understanding household water demand in Jordan, the research explores the impact of socioeconomic factors. It finds that while household size positively influences water demand, price elasticity remains low, suggesting a limited impact of price changes on water conservation. Al-Karablieh & Salman (2024)
7. A study in Hebei Province, China, focuses on the Analysis of Water Supply-Demand Based on Socioeconomic Efficiency and investigates how economic development influences water demand and supply. Their model analyzes scenarios with population growth, economic growth, water-saving measures, and a combination of these factors. The research found that economic development is a crucial driver that affects water balance. Interestingly, local population growth has minimal impact unless there's large-scale migration. The most significant impact on reducing water demand came from water-saving strategies, highlighting the potential for conservation efforts. However, even with combined approaches, the study predicts a water shortage in Hebei Province by 2030, emphasizing the need for ongoing water resource management. Yang et al. (2022)
8. Factors Affecting Water Supply and Demand and Their Relations focuses on the southeastern United States and explores the complex interplay between factors influencing water availability and use. They identify population growth, land-use changes, and climate variations as significant influences. The study emphasizes that these factors are interconnected. For instance, urbanization can decrease water availability through increased runoff and alter water demand patterns. The research highlights the need for comprehensive water resource assessments that consider natural and human-induced impacts to ensure sustainable water management in a changing environment. Pulhin (2018)
9. A Panel Analysis study on the Impact of Economic Development on Water Demand in China examines the relationship between economic development and water demand across various economic sectors in China. Their findings indicate that economic growth significantly increases water demand, particularly in the industrial sector. Interestingly, the study finds that water use efficiency improves

with economic development in the agricultural industry, suggesting a potential decoupling of water use and economic growth in agriculture with advancements in technology and practices. The research underscores the importance of analyzing water demand across different sectors to develop targeted water management strategies for sustainable economic development. Hao (2019)

10. Determinants of Household Water Demand in South West Nigeria explored how household characteristics influence water demand. They analyzed data from over 1,300 households, finding that factors like on-site water access significantly increased consumption compared to relying on off-site sources. Household size, income, and even the number of trips to collect water played a role. Their findings highlight the complex relationship between water access, infrastructure, and consumption patterns, particularly in developing regions. Iza-Dikko et al. (2023)
11. A Previous study on the Analysis of Household Daily Water Consumption Dynamics in the Tropical Environment focused on daily water use variations within households in a tropical city. Through a survey of 276 residents, they identified vital determinants beyond just total yearly consumption. Factors like time of day, seasonality, and even social events influenced water use. The study emphasizes the importance of understanding daily use patterns alongside yearly totals for effective water management strategies. Akindele & Ojo (2023)
12. Understanding Residential Water Demand: Insights from a Survey in a Mediterranean City: The study used survey data to analyze how sociodemographic and housing characteristics impacted water use. Their findings suggest that income, family size, the presence of children, and water-saving fixtures all play a role. Notably, the age of the building was a minor factor. This research highlights the need for targeted water conservation policies considering household demographics and infrastructure. Almeida et al. (2024)
13. Domestic Water Supply Deficits and the Disproportionate Burden on the Poor explores the global disparity in access to safe and reliable domestic water supplies. They estimate that over 2 billion people lack access to essential water services at home. The research highlights the unequal distribution of water resources, with low-income communities disproportionately affected by water shortages. The study proposes strategies for improving water supply infrastructure and ensuring equitable access to clean water. Hutton and Roche (2021)
14. An Assessment of Global Water Supply Vulnerability examines the vulnerability of global water supplies to climate change and population growth. They identify regions with high water stress, where water withdrawals exceed sustainable levels. The study emphasizes the need for improved water management practices and investments in infrastructure to ensure reliable water supplies for future generations. World Water Assessment Programme (WWAP) (2018)
15. Numerous studies, such as Sustainable Water Supplies for Urbanizing Populations, investigate the challenges of providing sustainable water supplies for rapidly growing urban populations. They analyze various water supply options, including rainwater harvesting, desalination, and wastewater reuse. The study emphasizes the importance of integrated water resource management and incorporating innovative technologies to meet future urban water needs. Larsen et al. (2019)
16. The study on the impact of climate change on water resources in Hebei Province, China, examines the relationship between environmental conditions and water resources in China's Hebei Province.They utilize a Water Resources Assessment and Planning model to analyze various scenarios, including population growth, economic development, and water-saving strategies. Their findings indicate that population growth minimizes water stress without large population influxes. However, economic

development significantly affects the water balance. Notably, the study highlights that climate change, not explicitly modeled here, is another crucial environmental factor influencing water availability in the region. Wang, J. (2017)

17. Building upon the previous study by the same authors, the Analysis of Water Supply-Demand Based on Socioeconomic Efficiency research delves deeper into water scarcity in Hebei Province. They acknowledge the limitations of their prior model and emphasize the need to incorporate climate change scenarios. This improved model factors in population growth, economic development, water-saving strategies, and potential climate change impacts. The simulations demonstrate that water-saving measures have the most significant influence on reducing water demand compared to population or economic growth scenarios. However, even with integrated planning, the study predicts a persistent water shortage in the region, underlining the urgency of addressing environmental factors affecting water resources. Bai, Y. (2019)
18. Focusing on India's basmati rice production, the study on the Impact of Agricultural Practices on Water Quality and Demand investigated how agricultural practices influence water quality and, subsequently, water demand. The research compared organic and conventional farming systems and their impact on water pollution during the monsoon season. Their findings suggest that traditional practices using excessive fertilizers and pesticides contribute significantly to water pollution. This polluted water can no longer be readily used for irrigation, necessitating increased freshwater extraction to meet agricultural demands. This emphasizes the need for sustainable farming methods to reduce water pollution and ensure long-term water security. Sihi et al. (2020)
19. Reassessing Water Scarcity Projections: The Role of Water Pollution challenges the projections of the UN World Water Development Report on future water scarcity. While the report acknowledges population growth and resource depletion, Liu et al. argue that the impact of water pollution is underestimated. Their analysis suggests that nearly 6 billion people might face clean water scarcity by 2050, potentially higher than previous predictions. The authors highlight the complex interplay between water demand, availability, and pollution. They emphasize the need for stricter regulations to control pollution and preserve water resources to achieve sustainable water security. Liu et al. (2019)
20. The study of the Looming Crisis: Water Pollution and its Effects on Water Supply explores the case of China's Loess Plateau, where naturally occurring elements and industrial activities contribute to water pollution. The research highlights the dangers of high sodium and salinity levels in rivers due to pollution. This polluted water is unsuitable for various purposes, including irrigation and drinking. Consequently, the region needs help in maintaining a reliable water supply. The authors call for improved water management strategies to address pollution and ensure access to clean water for future generations. Xiao et al. (2019)
21. With climate change a growing concern, the study Assessing the Impact of Climate Change on Future Water Demand using Weather Data explores how future weather patterns might influence water demand. Researchers focused on the relationship between weather variables, like temperature and water consumption. They found a positive correlation, meaning hotter temperatures lead to increased water demand. This highlights the importance of considering weather patterns in water resource management, especially when planning for potential climate change scenarios. By understanding how weather affects demand, we can develop more sustainable water management strategies for the future. Xenochristou et al. (2021)

22. Seasonal changes in hourly and daily water consumption patterns in rural water systems line study delves deeper into how seasonal variations affect water demand patterns, focusing on a rural water supply system. Researchers analyzed hourly and daily water consumption data across different seasons. They discovered distinct patterns depending on housing type. Detached houses showed a significant increase in demand during summer, likely due to outdoor water use for activities like lawn irrigation. Conversely, multi-family residences peaked in winter, potentially linked to increased indoor water needs for hygiene during colder months. This research emphasizes the importance of understanding how housing type and seasonality influence water consumption. Water management strategies can be tailored to specific user groups and seasonal variations by considering these aspects. Fiorillo et al. (2020)
23. The study on the Impact of Rising Temperatures on Urban Residential Water Demand investigates the relationship between rising temperatures and residential water demand in Phoenix, Arizona. Analyzing data over ten years, researchers found a significant increase in water use during hotter months. Each one °C rise in temperature corresponded to a 6% increase in daily water demand. The study attributes this rise to increased lawn watering, evaporative cooling for homes, and overall changes in water use behavior during hot weather. Sanchez, G. (2020)
24. Another study that focuses on The Effect of Climate Change on Water Availability in Drought-Prone Regions explores the impact of climate change's effect on water availability in drought-prone regions in China. The study utilizes climate models and hydrological simulations to predict future water resources. Results indicate increased temperatures will lead to higher potential evapotranspiration, causing more water to evaporate from the Earth's surface. This, coupled with changes in precipitation patterns, could significantly decrease water availability in these regions. Li et al. (2019)
25. The study on the Temperature Sensitivity of Water Use in California Agriculture focuses on the influence of temperature on agricultural water use in California. Researchers employed a water demand model to analyze historical data and predict future water needs under various temperature scenarios. Their findings suggest that a one °C increase in temperature could lead to a 4-7% increase in agricultural water demand. This rise is primarily driven by increased crop water requirements due to higher evapotranspiration rates in warmer climates. Tanasi et al. (2017)
26. The study on the Impact of Precipitation on Irrigation Demand in a Changing Climate investigates the relationship between Precipitation and peak water demand, particularly for irrigation, in Austria. The researchers employed a statistical model to analyze historical rainfall, temperature, and water consumption data. Their findings suggest an average increase in peak water demand of 3.5% with a corresponding rise in maximum temperature of 1.65°C. This indicates that reduced Precipitation due to climate change will likely lead to higher irrigation needs, stressing water resources. The study emphasizes the importance of considering climate projections when planning for future water demands. Stelzl et al. (2021)
27. Understanding Residential Water Demand in a Mediterranean City investigates water consumption patterns in a Mediterranean city. The research supports a positive correlation between household size and total water demand. Homes with more occupants tend to use more water overall. Interestingly, the study also found an "economy of scale" effect. While total consumption increases with household size, water use per person decreases in households with 5-6 members compared to smaller ones. This suggests that some water uses, like laundry or showering, remain relatively constant regardless of occupants, leading to decreased per capita consumption in larger households. Turi et al. (2024)

28. A previous study on the Analysis of Household Daily Water Consumption Dynamics in the Tropical Environment examines factors influencing daily water use in a tropical city. Using a survey of 276 households, the study identified household size as one of twelve significant determinants of daily water consumption. Interestingly, the analysis found a weak overall correlation between most factors, suggesting a complex interplay of influences on water use. However, household characteristics, including size, emerged as a critical factor explaining a significant portion of the variation in daily water consumption. Akindele & Ojo (2023)
29. The impact of long-term water temperature increases and stratification on big, artificial lakes used as water sources in South Korea investigated the relationship between water volume, temperature, and stratification in South Korean artificial lakes. They found a significant negative correlation between water volume (represented by retention time, the time it takes for the lake to replace its water completely) and surface water temperature. Lakes with lower water volume experienced faster warming rates. This suggests smaller water bodies are more susceptible to temperature fluctuations due to reduced heat buffering capacity. Additionally, stronger thermal stratification (separation of warm surface and more relaxed deepwater layers) was observed in lakes with lower water volume. This limits vertical mixing and heat transfer within the lake, further amplifying surface water warming. These findings highlight the importance of water volume in regulating lake temperatures, with implications for aquatic ecosystems and water resource management under climate change scenarios. Lee, J. (2021)
30. Impacts of temperature and Precipitation on the spatiotemporal distribution of water resources in Chinese megacities: the case of Beijing examined the influence of temperature and Precipitation on water resources in Beijing, China. The study revealed a negative correlation between water resources and temperature and a positive correlation with rainfall. Higher temperatures increased water demand for various purposes, including irrigation and urban cooling. Conversely, increased Precipitation contributed to higher water inflows and replenished water reserves. The analysis also identified regional variations within the city, with areas experiencing the urban heat island effect exhibiting higher temperatures and lower water resources. These findings emphasize the crucial role of temperature and Precipitation in shaping water availability in urban environments. The study underscores the need for integrated water resource management strategies that consider the combined effects of climatic factors on water supply and demand. Wang et al. (2018)
31. A Previous study on Precipitation Patterns and Drought, MDPI explores the connection between precipitation patterns and drought in eastern Gansu, China, a region heavily reliant on rain-fed agriculture. Researchers analyzed daily data from 1960 to 2017, identifying a link between drought occurrence and the distribution of Precipitation throughout the year. Interestingly, the study suggests frequent weak precipitation events, rather than low total rainfall, are more closely associated with droughts. This highlights the importance of considering the amount of Precipitation and its distribution throughout the year. The findings can inform water management strategies in drought-prone regions, where consistent rainfall is crucial for agricultural productivity. MDPI (2017)

CHAPTER 3: RATIONALE

Every living thing needs water to function properly and societal development. Access to clean and reliable water supplies underpins public health, sanitation, and economic activity. Yet, many regions worldwide need help in meeting their water demands due to population growth, climate change, and infrastructure

limitations. Safe and reliable access to water is a fundamental human right and a critical element for public health, economic development, and environmental sustainability. The United Nations explicitly recognizes the human right to water and sanitation, emphasizing its importance for a life of human dignity. The Philippines faces a growing challenge in managing its water resources. A recent study by The World Bank (2019, High and Dry: Water Security in the Philippines) sheds light on this critical issue. The research analyzes water demand and supply across the archipelago, highlighting factors like population growth, urbanization, and agricultural expansion pushing demand upwards. On the supply side, the study examines limitations and the lack of readily available water. aging infrastructure, and environmental pressures. These interconnected issues are key to developing successful water management strategies. By delving into this related study, we can develop lasting solutions to guarantee clean water for all Filipinos.. Understanding also Cebu's water situation is crucial for sustainable development. A relevant study by the Mactan Water Resource Management Board (2020) entitled "Water Security Roadmap for Metro Cebu 2020-2040" provides valuable insights into the current water demand and supply dynamics in Cebu. The study analyzes population growth, industrial development, and domestic water consumption data, highlighting the increasing pressure on Cebu's water resources. It examines existing water sources like rivers and groundwater and their limitations due to factors like seasonal variations and potential contamination. By analyzing the study, researchers can gain a deeper understanding of the gap between Cebu's water demand and supply, allowing us to develop effective water management strategies for the future. In Danao City, Cebu, the Danao City Waterworks (DCWW) is responsible for providing this essential resource for all 32 barangays within its jurisdiction. With a population exceeding 150,000 residents, ensuring sufficient and reliable water supply is paramount for the city's well-being. However, despite its crucial role, the efficiency of the water supply system in Danao City merits investigation.
Several factors could be hindering the water supply's efficiency in Danao City. An imbalance between water needs and available resources could be a factor in Danao City. More people and more water use in homes and factories, and agricultural demands can all contribute to a growing strain on existing water supplies. Additionally, aging infrastructure, leaks in the distribution network, and unaccounted-for-water (UFW) – water produced but lost before reaching consumers – all contribute to inefficiencies in water delivery systems. UFW can occur for various reasons, including metering inaccuracies, illegal connections, and faulty pipes. Understanding the specific factors affecting Danao City's water supply system is essential for addressing current challenges and ensuring a sustainable water future for the city's residents.
The research aimed to shed light on the current state of water supply and demand in Danao City. By examining data on water production from the Danao City Waterworks, water consumption patterns within different barangays, and potential losses due to leaks and UFW, the study will identify areas for improvement and inform the development of effective strategies to optimize water management within the city. This will improve Danao City's residents' access to clean water and promote the community's well-being. Furthermore, the findings of this research can apply to other cities facing similar water supply challenges, promoting best practices for sustainable water management across the Philippines.

CHAPTER 4: METHODOLOGY

Aim

The study aimed to evaluate Danao City's water management system for sustainability through statistics and a linear regression model.

Objectives

- To investigate the city's water system profile considering social factors (number of households), economic factors (household water consumption and supply volumes), and environmental factors (water pollution, temperature, and Precipitation).
- This study aimed to investigate the relationships between water consumption and the number of households, water supply and temperature, and water supply and Precipitation.
- To develop a model to forecast future water demand based on household count and water supply based on temperature and Precipitation.

Hypothesis

There is no significant relationship between:

Ho_1. water consumption and number of households,

Ho_2. water supply and temperature, and,

Ho_3. Water supply and Precipitation.

Data Gathering Procedure

This study used historical and correlational predictive research methods. All the primary data were taken from the Danao City Water Works, Danao City Engineering and Planning Office records, and World Weather Online.

Historical data for the period 2019 to 2023 were collected. The Danao City Water Works System provided detailed historical information on water demand since 2019 and current water resources. An interview with the Heads of Office of the departments mentioned in Danao City supported this. Based on the data, the most significant influences on Water demand were identified: social, economic, and environmental factors.

Treatment of the Data

In the study, the researchers investigated the potential connection between water demand and water supply. To achieve this, the researchers employed two statistical techniques: Pearson Product Moment Coefficient Correlation and Simple Linear Regression Analysis.

Pearson Product Moment Coefficient Correlation (r): This test helps us understand how strong the linear trend is between two continuous variables, and whether they tend to increase or decrease together. It produces a value (r) ranging from -1 to +1. A positive r indicates a positive correlation (as water supply increases, demand also increases), while a negative r signifies a negative correlation (more supply leads to less demand). A value near 0 indicates a weak or negligible association association. The formula for r is:

$$r = n \sum xy - \sum x \sum y \div \sqrt{(n \sum_x 2 - (\sum_{x)} 2)(n \sum_y 2 - (\sum_{y)} 2)}$$

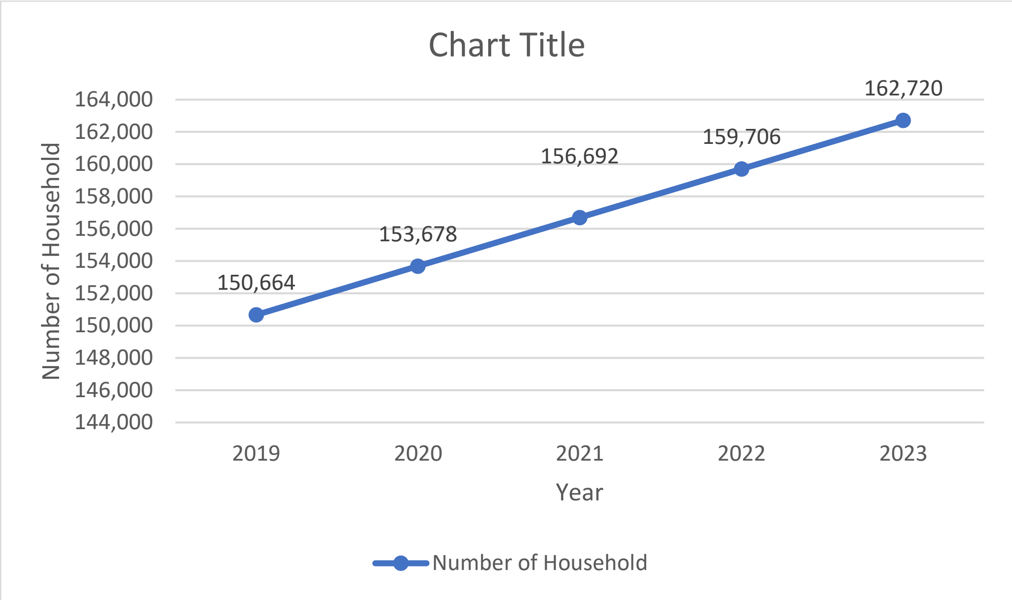
Simple Linear Regression Analysis: This technique goes beyond correlation by establishing a mathematical model that describes the linear relationship between water supply (independent variable) and water demand (dependent variable). This model allows the researchers to predict water demand based on specific water supply values and assess the strength of this prediction through the coefficient of determination (R^2). R^2 tells how much of the variation in water demand that the variations in water supply can explain. The formula to be used is y=a+bx.

CHAPTER 5: RESULTS AND DISCUSSION

This chapter examined the findings in the study. It also profiles the Danao City waterworks system and answers the questions posted in Chapter I, such as the factors that greatly contributed to the study.
Profile of the Danao City Water Works System

Social Factors

Figure 1. Number of Households



The line graph showed the number of households within five years in Danao City from 2019 to 2023. There is an upward trend in the number of households over this period. According to the graph, the number of households in Danao City increased from around 150,664 in 2019 to 162,720 in 2023. This growth, potentially linked to Danao City's 2% population increase, translates to a rise in water demand. Population growth significantly contributes to water scarcity as more people compete for this vital resource. While the challenge is recognized, translating this awareness into actionable plans is crucial.

Economic factor

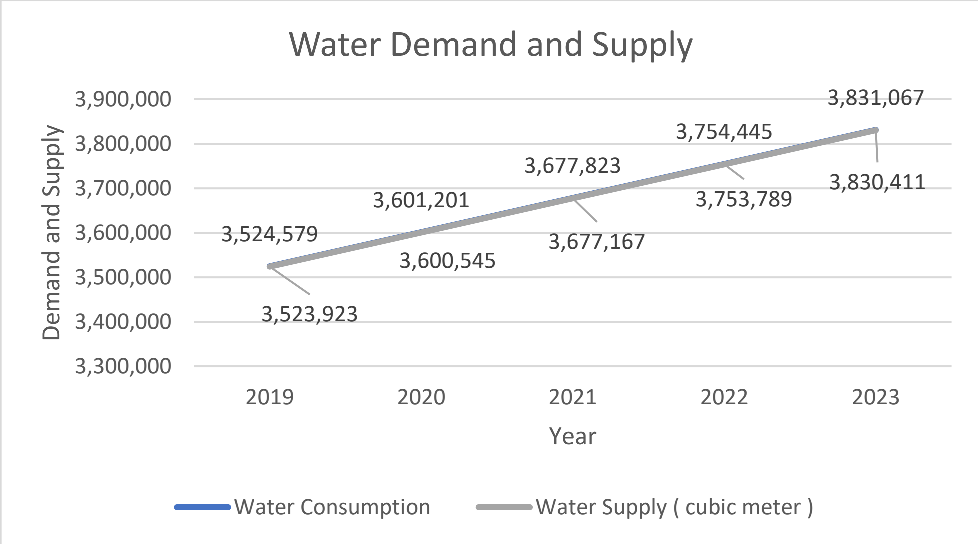
Water demand and supply

Table 1. Water Supply and Demand in Danao City

Year	Water consumption (m^3)	Water supply (m^3)
2019	3,524,579	3,523,923
2020	3,601,201	3,600,545
2021	3,677,823	3,677,167
2022	3,754, 445	3,753,789
2023	3,831,067	3,830,411
TOTAL:	18,389,115 m^3	18, 385,839 m^3

The table showed water consumption and supply in Danao City over a five-year period. Based on the total difference of the water demand and supply, which is 3,120,637 m3. With the present capacity, Danao City Water Works can only supply approximately 9,000 m3 daily instead of 10,000 m3. Danao City has become a place of interest to researchers because of the upcoming launching of the Danao City Bulk Water System that will be supplied to the Metropolitan Cebu Water District (MCWD). Thus, more than the water supply will be needed for the coming years.

Figure 2. Water Demand and Supply



The data presented on the chart reveals a critical imbalance between water supply and demand in Danao City. Daily water needs exceed available resources by a significant margin of 656 cubic meters. This disparity indicates a potential water scarcity issue that could have severe consequences for residents.
Pinpointing the root of this imbalance is essential. Aging infrastructure, population growth, and inefficient water management practices could all be contributing factors. Addressing these issues requires a multi-pronged approach. Upgrading water treatment facilities, implementing leak detection and repair programs, and promoting water conservation initiatives among residents are all crucial steps toward achieving a sustainable water future for Danao City.

Environmental Factors

Water Pollution

As of the 2019 report of Danao City Water Works, all the water sources show a negative result of water contamination. Hence, water pollution does not affect the water supply volume since water treatment was done before distribution.

Weather Seasonal Variations

Table 2. Temperature and Precipitation of Danao City (2019-2023)

	2019	**2020**	**2021**	**2022**	**2023**
Average Temperature (°C)	30 °C	31°C	32 °C	30°C	31 °C
Total Precipitation (year)	145 mm	193 mm	241 mm	289 mm	337 mm

The table revealed a concerning trend: average temperature and total Precipitation have increased over the past five years. Danao City has seen a rise in average temperature from 30°C to 32°C, alongside a jump in total Precipitation from 145 mm to 337 mm. This suggests a shift towards warmer and wetter conditions. This data is particularly relevant to your water demand and supply research. Warmer temperatures often lead to increased water needs for irrigation and household purposes. Furthermore, changes in precipitation patterns can strain water supplies, with both higher volumes and more significant variability posing challenges. Grasping these hurdles is key to creating successful regional water management strategies.

Figure 3. Average Annual Temperature of Danao City (2019-2023)

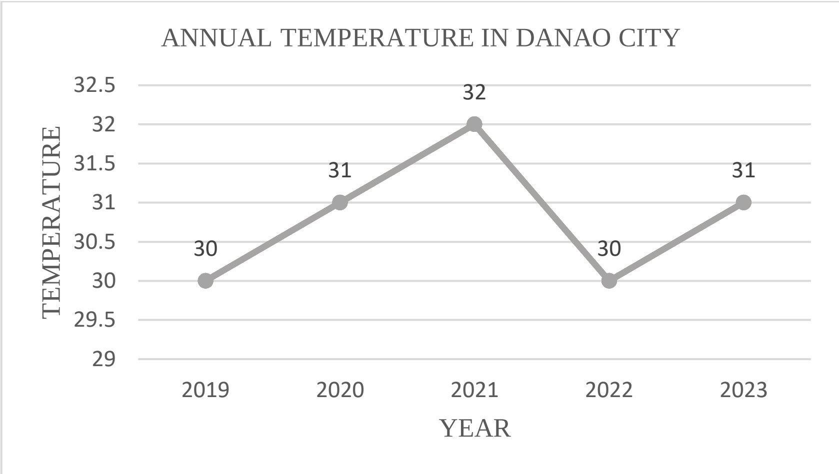


Figure 4. Average Annual Precipitation of Danao City (2019-2023)

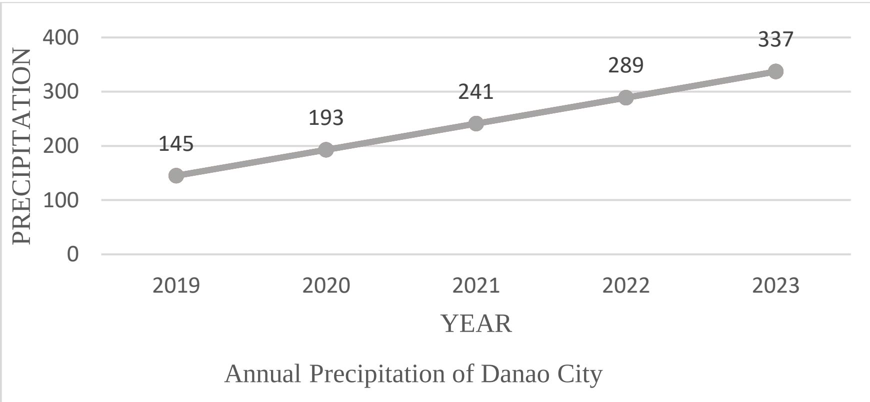


Table 2, Figure 3, and Figure 4 revealed a concerning trend over the past five years: both average temperature and total Precipitation have increased over the past five years. Danao City has seen a rise in average temperature from 30°C to 32°C, alongside a jump in total Precipitation from 145 mm to 337 mm. This suggests a shift towards warmer and wetter conditions. This data is particularly relevant to your water demand and supply research. Warmer temperatures often lead to increased water needs for irrigation and household purposes. Furthermore, changes in precipitation patterns can strain water supplies, with both higher volumes and more significant variability posing challenges.

Significant Relationship

The researchers utilized two statistical tools to explore the connection between water demand and supply and other factors. The Pearson correlation coefficient (r), ranging Employs a -1 to 1 range to quantify the strength and direction of their linear association (e.g., positive r means more supply leads to more demand). Simple linear regression builds on this by creating a model to predict water demand based on supply. This model also provides a coefficient of determination (R^2) indicating the proportion of demand variation explained by supply changes.

Water Consumption and Number of Households

Table 3. Relationship between Water Consumption and No. of Household

Year	Water consumption	No. Of households
2019	3,524,739	150,664
2020	3,601, 201	153,678
2021	3,677,823	156,692
2022	3,754,445	159,706
2023	3,831,067	162,720

Table 3 showed the historical data on water consumption and the number of households in Danao City for the past years. Using the Pearson Product Moment Coefficient Correlation, it was computed and shown in Appendix C that r =12, which is greater than 1, which implies that the strength of the relationship is muscular. This means there is a strong, significant relationship between water consumption and increased households since population growth means mounting demand and competition for water for domestic uses. Therefore, the null hypothesis was rejected.

Water Supply and Temperature

Table 4. Relationship Between Water Supply and Temperature

Year	Temperature (°C)	Water Supply
2019	30	3,523,923
2020	31	3,600,545
2021	32	3,677,167
2022	30	3,753,789
2023	31	3,830,411

Table 4 showed the historical data on the water supply and temperature of Danao City for the past years. Using the Pearson Product Moment Coefficient Correlation, it was computed that r = 0.19, which shows that the strength of the relationship is muscular. This means a significant relationship exists between water supply and temperature because the computed value of r lies on the positive side. Hence, the null hypothesis was rejected.

Water Supply and Precipitation

Table 5. Relationship between Water Supply and Precipitation

Year	Precipitation (mm)	Water Supply (m^3)
2019	145	3,523,923
2020	193	3,600,545
2021	241	3,677,167
2022	289	3,753,789
2023	337	3,830,411

Table 5 showed the historical data of Danao City's water supply and total Precipitation for the past years. Using the Pearson Product Moment Coefficient Correlation, r = 1 was computed and shown in Appendix C, which shows that the relationship is strong. This means that there is a significant relationship between water supply and Precipitation; therefore, Precipitation is not directly proportional to water supply. The null hypothesis was rejected.

Forecast

Projected Volume of Water Demand and Number of Household

Using the Simple Linear Regression Analysis, the model sets the time boundary from 2024 to 2028. The data of some variables need to be analyzed before being put into the model to predict the volume of water demand. By analyzing the household data, the final regression equation for the volume of water demand in terms of household growth is:

If (2024), y= 86783.8722
(2025) y= 86783.89586
(2026) y= 86783.91951
(2027) y= 86783.94316
(2028) y= 86783.96681

Table 6. Projected Volume of Water Demand in Terms of Number of Households

Year	Number of Households	Water Demand (m^3)
2024	237,448	3,611,523
2025	240,462	3,687,9,85
2026	243,476	3,764,607
2027	246,490	3,841,229
2028	249,504	3,917,851

Table 6 showed the projected volume of water demand in terms of the number of households for 2024 and the next four years (2024-2028). Based on the household growth model, water demand is expected to rise steadily between 2024 and 2028. The number of households is projected to climb by 5.0% from 237,448 in 2024 to 249,504 in 2028. This translates to a water demand increase of 8.5%, going from 3,611,523 cubic meters in 2024 to 3,917,851 cubic meters in 2028.

Projected Volume of Water Supply in terms of Temperature

Using the Simple Linear Regression Analysis, the model sets the time boundary from 2024 to 2028. The data of some variables need to be analyzed before being put into the model to predict the water supply volume. By analyzing the precipitation data, the final regression equation for the volume of water supply in terms of temperature is:

If (2024), y= 26.00353423
(2025) y= 26.00353554
(2026) y= 26.00353684
(2027) y= 26.00353815
(2028) y= 26.00353945

Table 7. Projected Volume of Water Supply in Terms of Temperature

Year	Temperature (°C)	Water Supply
2024	41	3,523,949
2025	42	3,600,597
2026	43	3,677,193
2027	41	3,753,815
2028	42	3,830,437

Table 7 showed that Year by year, the water supply volume is expected to increase slightly, from its computed regression equation y=26.00353423. The temperature is also expected to rise slightly, from 41 degrees Celsius in 2024 to 42 degrees Celsius in 2028. However, it's important to consider limitations, as the data shows that there has been just a slight increase in the water supply over the year in terms of temperature.

Projected Volume of Water Supply in terms of Precipitation

Using the Simple Linear Regression Analysis, the model sets the time boundary from 2024 to 2028. The data of some variables need to be analyzed before being put into the model to predict the water supply volume. By analyzing the precipitation data, the final regression equation for the volume of water supply in terms of Precipitation is:

If (2024), y= 6523355.042

(2025) y= 6524951.333

(2026) y= 6526547.625

(2027) y= 6528143.917

(2028) y= 6529740.208

Table 8. Projected Volume of Water Supply in terms of Precipitation

Year	Precipitation (mm)	Water Supply (m^3)
2024	385	10,047,278
2025	433	10,125,496
2026	481	10,203,715
2027	529	10,281,933
2028	577	10,360,152

The data showed a prediction of the water supply volume in Precipitation over five years from 2024 to 2028. The data table shows the projected water supply volume in cubic meters (m^3) based on precipitation levels in millimeters (mm) for each year. As precipitation levels increase, the water supply volume is also expected to increase. By 2028, with a predicted precipitation level of 577 millimeters, the water supply is expected to be 10,360,152 cubic meters.

Projected Volume of Water Consumption and Supply

Using the Simple Linear Regression Analysis, the model sets the time boundary from 2024 to 2028. The data of some variables need to be analyzed before being put into the model to predict the water supply volume. By analyzing the water consumption, the final regression equation for the volume of water supply in terms of water consumption is:

If (2024), y= 4010528.718

(2025) y= 4053267.872

(2026) y= 4096007.026

(2027) y= 4.138746177820E+13

(2028) y= 4181485.334

Table 9. Projected Volume of Water Supply in terms of Water Consumption

Year	Water consumption (m^3)	Water supply (m^3)	% greater / lesser
2024	5,570,252	7,534,452	26% greater
2025	5,646,874	7,653,813	26% greater
2026	5,723,496	7,773,174	26% greater
2027	5,800,119	7,892,535	27% greater
2028	5,876,741	8,011,896	27% greater
TOTAL:	28,617,482 m^3	38, 865,870 m^3	

The data showed a projected rise in water supply over a five-year period. While water consumption is expected to increase by a certain percentage, the projected water supply is expected to grow slightly. This translates to a widening gap between supply and consumption over time. The projected water supply is expected to comfortably outpace demand over the next five years, with an increase of around 26% to 27% by 2028. This suggests ample water will meet projected needs for more upcoming years.

CHAPTER 6: CONCLUSION AND RECOMMENDATION

This chapter presented the conclusions reached and recommendations made based on the analysis in the preceding two chapters. Based on the findings, several conclusions were made, with specific recommendations suggested. This chapter features two sections: (1) conclusions based on the study results and (2) recommendations for the study.

Conclusion

The study found a strong positive correlation between water consumption and the number of households in Danao City. This indicates that a growing population will lead to increased water demand. However, developed models project a 26%-27% surplus in water supply despite rising temperatures and Precipitation over the next five years. This suggests that Danao City can meet the projected water demand for the timeframe considered (2024-2028) if it uses the computed models to forecast the water demand and supply for the upcoming five years and continue with current water management practices. It's important to remember that these models have limitations, and continuously monitoring water usage and supply remains crucial for long-term water security. To forecast the water demand and water supply for over five years from now, the model to be used is y== 4010528.718.

Recommendation

While Danao City's water supply is expected to keep pace with rising demand (2024-2028), proactive measures are still recommended due to a growing population. The models developed in this study, particularly the one with the equation y = 4010528.718, should be continuously utilized for forecasting water demand and supply over the next five years and beyond. This will allow informed decision-making regarding water management strategies, including public awareness campaigns or infrastructure improvements, to ensure long-term water security for Danao City's residents.

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