INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY: APPLIED BUSINESS AND EDUCATION RESEARCH
2025, Vol. 6, No. 3, 1234 – 1273
http://dx.doi.org/10.11594/ijmaber.06.03.20

Research Article

Quantifying Water Footprints in Selected Barangays of Sofronio Española, Palawan: Advancing Watershed Conservation and Management

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Article history:
Submission 27 January 2025
Revised 28 February 2025
Accepted 23 March 2025

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ABSTRACT

This study examines the water footprint and watershed management practices in Sofronio Española, Palawan, focusing on sustainability, conservation, and efficient resource use. Using a mixed-method approach, the research combines quantitative and qualitative analyses to assess water resource conditions, consumption trends, and environmental impacts within the Pulot Watershed.

The primary objectives are to evaluate water supply components, water footprints, and resource conditions, understanding the broader environmental consequences, with the goal of promoting sustainable water management strategies.

Quantitative data were collected through household surveys with metered water connections using stratified sampling, alongside secondary data from water system records. These data were analysed using trend analysis, forecasting models, and GIS-based spatial mapping. Qualitative data from interviews with key informants provided insights into local perspectives on water conservation, management challenges, and the effectiveness of policies.

The findings reveal that rapid population growth, deforestation, and land-use changes due to agriculture, mining, and urbanization are significantly impacting the Pulot Watershed. These issues, compounded by slash-and-burn farming and inadequate water management, are contributing to environmental degradation and jeopardizing the watershed's ability to meet growing water demands. The study highlights critical gaps in governance, public awareness, and stakeholder involvement, emphasizing the need for integrated water resource management.

Key recommendations include addressing population growth, improving water management systems, enhancing infrastructure, promoting community participation, and implementing pollution control measures and habitat restoration. These actions align with Sustainable Development Goal 6 (Clean Water and Sanitation) and

How to cite:
Jabagat, V. C. (2025). Quantifying Water Footprints in Selected Barangays of Sofronio Española, Palawan: Advancing Watershed Conservation and Management. *International Journal of Multidisciplinary: Applied Business and Education Research*. *6*(3), 1234 – 1273. doi: 10.11594/ijmaber.06.03.20

aim to ensure the long-term health and sustainability of the watershed.

***Keywords**: Conservation, Management, Water footprints, Watershed*

Background

One of life's most basic needs is water. The world's usable water resources make up around 0.3% of the total. In many areas, there are existing water shortages, and over a billion people lack access to clean drinking water. This circumstance is one of the most significant signs that we need to be extremely mindful of and attentive to our water resources. The need for water is growing along with the global population (Kilic, 2020).

The water footprint refers to the total volume of freshwater used to produce goods and services, encompassing blue water (from surface and groundwater), green water (from rain), and grey water (for pollution). It provides a framework for understanding the impact of human activities on water resources and is essential for managing water scarcity. Recent studies, such as Hoekstra and Mekonnen (2023), emphasize the need for a broader approach to water footprint analysis, incorporating both the quantity and quality of water, particularly in areas facing water stress.

The increase in the population of the world and the level of wealth of humans is expected to withdraw more freshwater. Freshwater is indeed a limited resource, global per capita water availability surely drops, and water shortage happens (Musie, 2023). Its availability varies significantly depending on factors such as geographical location, climate conditions, population density, and water management practices in the locality.

Quantifying the water footprint of the Sofronio Española community in advance is vital to ascertain whether the Pulot watershed can sustainably meet the water demand of both current and future generations who depend on these resources.

Pulot watersheds significantly impact freshwater production since the possibility of rapid population growth in Sofronio Española as a newbie municipality in Palawan, may exert pressure on its health and functionality. Increased demand for land and resources leads to deforestation, urbanization, and expansion of agricultural activities, altering the natural landscapes and hydrological processes within the watershed.

The municipality is also dealing with extensive deforestation and mining activity, which may influence the watershed and put further demand on the water supply. The potential effects of these environmental factors on the watershed's capacity to supply water to fulfill the increasing demand were investigated in this study. The research endeavours to provide insights into sustainable water management methods that can guarantee a stable water supply for the inhabitants of Sofronio Española in the future by comprehending the magnitude of these effects of climate change. The main objectives are to assess the components of water supply, analyze water footprints, and evaluate resource conditions, while understanding the wider environmental impacts, with the aim of promoting sustainable water management strategies.

The transformation of a significant portion of land in Sofronio Española into Palm Tree plantation, mining sites, and agricultural expansion poses significant threats to watershed health and resilience The continued practice of the Kaingin System is still rampant in rural areas contributing to deforestation, soil erosion, and degradation of water catchment areas. Slash and burn also provide a source of livelihood in rural areas in Sofronio Española that releases large amounts of carbon dioxide into the atmosphere contributing to air pollution and climate change. Also, the loss of vegetation reduces the land's ability to absorb rainfall, leading to sedimentation of water bodies and degradation of water quality (USAID Philippines, 2011).

As the population increases, the demand for household water usage inevitably escalates,

leading to various challenges. Increased demands put pressure on existing water infrastructure, potentially leading to strains on supply systems and distribution networks. Additionally, it can exacerbate environmental issues, such as depletion of water sources, land cover changes, and vegetation.

Recognizing fresh water as an indispensable necessity for the people, there is a pressing need to quantify the water footprints of the municipality.

Statement of the Problem

This study aimed to quantify the water footprint in selected barangays of Sofronio Española for the advancement of watershed conservation and management. Specifically, it sought to answer the following questions?

1. What are the water supply components of the Sofronio Española Waterworks System as to the following?
   a. source of water.
   b. year of operations.
   c. the number of households with active meter water connections and
   d. the volume of production per year?
2. What is the water footprint in the selected barangay of Sofronio Española as to domestic use of water consumption per year?
3. What is the condition of the Pulot watershed based on the following.
   a. environmental factors- land cover (open and closed forest)?
   b. social factors
      1) population growth and water demand?
      2) social awareness and perception towards watershed conservation and management?

Significance of the Study

For a wide range of stakeholders, this study was important to the Local Government Unit (LGU) and its affiliated offices, including the Palawan Council Development Office, the Municipal Environment and Natural Resources Office, the Municipal Planning Development Office, and the Sofronio Española Waterworks System. For the future management and conservation of Pulot Watershed, the comprehensive data produced by this study served as an important resource. The study contributed to improving current watershed management and sewerage system policies and regulations by offering empirical support, making them more efficient and environmentally sensitive.

Furthermore, this study offers the researcher a singular chance to solve urgent environmental issues that impact the neighborhood while also adding to the growing corpus of scientific knowledge. Working together with the LGU and its offices promotes the development of solid bonds and a cooperative strategy for resolving issues about water. In addition to improving local governance, this cooperative endeavour gives community stakeholders the ability to actively participate in conservation initiatives.

Beyond government offices, this study is important for non-governmental organizations (NGOs), private groups, and upcoming scholars. The results can be used to guide these organizations' initiatives, plans, and projects that enhance resource management and environmental sustainability. Members of the community will also gain important insights from the research, which will promote local stewardship and increase understanding of the Pulot Watershed's significance. The study's goal is to promote a comprehensive strategy for environmental management that involves all parties involved and creates a resilient and sustainable environment for present and future generations.

The Sustainable Development Goals (SDGs), especially Goal 6, which seeks to guarantee universal access to and sustainable management of water and sanitation, make this study noteworthy. The research supports the goals of encouraging integrated water resources management, increasing water-use efficiency, and improving freshwater production by examining the watershed's capacity and resource conditions. To achieve the SDGs essential components of promoting community involvement, ensuring ecosystem health, and providing equal access to water, the study's recommendations will be helpful. In the end, this study supports international initiatives to encourage sustainable behaviours and guarantee water security for future generations in addition to addressing regional water issues.

Scope and Delimitation of the Study

This study addresses several critical issues regarding the water supplies and environmental circumstances in Sofronio Española. It provides an in-depth examination of the Sofronio Española Waterworks System, focusing on the components of water resources by evaluating their sources, distribution, and availability. The analysis emphasizes not only the status of these resources but also their sustainability for future generations, considering the growing demands on water supply due to population growth and climate change.

The study also explored the water footprint of selected barangays, highlighting variations in water usage patterns and identifying specific areas where conservation efforts were needed. By analysing domestic, agricultural, and industrial water consumption, the research aimed to shed light on trends that could inform more efficient water management practices. In addition to quantitative data, the study incorporated qualitative insights from local stakeholders, including residents, community leaders, and government officials. This approach aims to understand their perspectives on water management, conservation practices, and the challenges they face in accessing clean water. Engaging with the community will provide a comprehensive view of the social dynamics surrounding water resources.

Despite potential limitations, such as difficulties in data collection and the variability of water quality due to environmental factors, this study aspires to deliver valuable insights into the water resources and watershed management landscape in Sofronio Española. The findings are intended to contribute to informed decision-making processes, guiding local authorities and policymakers in developing effective water resource management and conservation strategies.

Ultimately, this research aims to support sustainable practices that ensure water availability for current and future needs, thereby enhancing the community's resilience against water scarcity and environmental degradation.

Methods

This study employed a mixed-method approach, integrating both quantitative and qualitative data collection techniques to comprehensively assess the water resource conditions and management needs in the Pulot Watershed of Sofronio Española.

For the quantitative component, the researcher analyzed water usage data to determine the water footprint of consumers in selected barangays, focusing on domestic water consumption and residents' awareness of watershed conservation and management. Stratified sampling techniques were employed to select participants, specifically targeting households with active water connections in residential areas. Statistical tools included exponential growth models to project future water consumption trends based on current usage patterns, and trend analysis using time series data to identify long-term fluctuations and seasonal variations in water use. Additionally, forecasting scenarios were developed to predict future water demand, while logarithmic calculations were used to assess the rate of change in consumption over time, offering a more precise understanding of water usage dynamics. These methods are particularly suitable for calculating water footprints, as they allow for an accurate assessment of water use over time, accounting for both current consumption and projected future demands, thus providing a comprehensive understanding of the water footprint in the selected areas.

Descriptive statistics, including measures of central tendency (mean, median) and dispersion (standard deviation, range), summarized water consumption patterns and highlighted variability across different households. Frequency distributions and percentages were also used to assess the prevalence of certain water usage behaviours and conservation practices.

For the qualitative component, semi-structured questionnaires were used to collect narrative insights on water usage, water systems, and management practices. Descriptive statistics were applied to summarize these insights, providing a broader context for understanding water resource conditions, water footprints, and watershed conservation. The sample consisted of key informants, specifically individuals in leadership roles with expertise in environmental issues, such as heads of local

offices or officials involved in water resource and environmental management. This sampling approach is known as purposive or judgmental sampling, as participants were selected based on their relevant knowledge and expertise.

Additionally, Geographic Information System (GIS) was used with secondary data from the Palawan Council for Sustainable Development Office to analyzed water distribution, usage, and land cover in the watershed. However, limitations included resolution constraints, affecting data precision, data availability issues, with some regions lacking up-to-date information, and temporal resolution inconsistencies, with gaps in historical and time-series data.

The participants in this study included a range of key stakeholders involved in water management and environmental conservation. These participants consisted of representatives from the Municipal Planning and Development Office (MPDO), Municipal Environment and Natural Resources Office (MENRO), the Sofronio Española Waterworks System Office, and the Palawan Council for Sustainable Development (PCSD).

Another group of participants in this study were members of the Sofronio Española Water System who had active water meter connections in the residential areas of the selected barangays, specifically Barangays Iraray, Pulot Center, Pulot Interior, Pulot Shore, Panitian, Labog, and Punang. These participants, aged 18 to 54 years old, provided valuable insights into water usage patterns, consumption habits, and their awareness of water conservation practices.

By including this group, the study captured a broad range of perspectives on how water was managed at the household level and how the community perceived and engaged with conservation efforts facilitated by the water system. Their input was crucial in assessing the effectiveness of the water system's initiatives and understanding the practical challenges that residents faced regarding water conservation and management. This demographic selection ensured that the participants were of legal age to provide informed consent while also representing a diverse cross-section of the community.

The study took place in Sofronio Española, the newest municipality in Palawan, officially established on June 5, 1995, through Republic Act 7679. According to the 2020 Census, the population was 37,416, which accounted for 1.16% of the total population in the MIMAROPA Region and 3.98% of Palawan's overall population. The municipality had a population density of 79 people per square kilometre, or 204 people per square mile. This area was expected to experience annual population growth, as indicated by data from the Philippine Statistics Authority

Geographically, Sofronio Española is situated in the southern part of Palawan along its eastern seaboard, spanning kilometres 128.1 to 166 of the National Highway. It is bordered by the municipalities of Narra to the north, Brooke's Point to the south, Quezon to the west, and the Sulu Sea to the east. The municipality is approximately 163 kilometres from Puerto Princesa City.

The municipality consists of nine barangays: Abo-Abo, Iraray, Isumbo, Labog, Panitian, Pulot Center, Pulot Interior, Pulot Shore, and Punang, each serving as hubs of cultural, agricultural, and administrative activities.

Result and Discussion

The Water Supply Component in Sofronio Española Palawan

Source of Water

The municipality water system relies on the Pulot watershed as the sole source of water for its distribution system. This watershed, covering a total area of 18,158 hectares, with 17,186 hectares located within the municipality, is the only defined catchment area in the region. It stretches from the base of the Mantalingahan

Mountain Range and encompasses several barangays, including Pulot Interior, Pulot Shore, Pulot Center, Punang, Labog, and Iraray, as well as a disputed area in Calasaguen and a portion of the Municipality of Quezon.

The watershed encompasses all land and water resource both groundwater and surface water and consists of multiple sub-watersheds. The highest elevation within the watershed is

located at the western tip of Tapisan Creek, at about 1,100 meters above sea level.

The lowest point is along the shores of Pulot Shore, which is approximately 20 meters above sea level. (Comprehensive Development Plan 2020-2026. MPDO–Sofronio Española)

Table 1. Sofronio Española Watershed and Sub-watersheds Area (Comprehensive Development Plan 2020-2026 MPDO–Sofronio Española, 2024)

Watershed	Watershed Area inside MMPL (ha)	Total Area (ha) of Sub-watersheds
Mambalot-Pilantropia River	75.52	
Lamikan River	612.71	
Aplian-Caramay River	100.76	
Pulot River	5384.45	18,192.31
Labog River	224.18	5,365.92
Panitian River QZ	673.00	
Total	**7,070.62**	**23,558.23**

The primary drainage system is the Pulot River, which flows for 15 kilometres through the catchment area. The river passes through three barangays: Pulot Interior, Pulot Center, and Pulot Shore. Its headwaters originate from the steep slopes of Barangay Punang, with major tributaries including the Pasi, Tagusao, and Maribong Rivers.

There are also several intermittent creeks feeding into the Pulot River, though these may run dry in the summer. The river's highest elevation is between 125 and 130 meters above sea level.

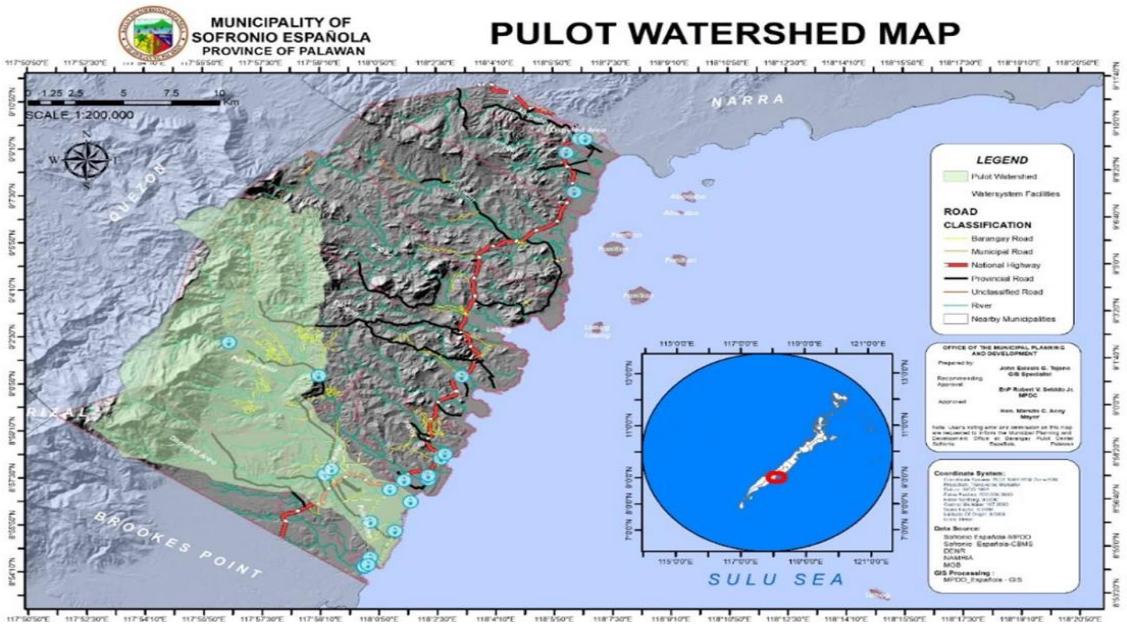

Figure 1. Pulot Watershed Map (GIS Generated. MPDO-Sofronio Española, 2024)

Annual Rainfall

Sofronio Española, a municipality in southern Palawan, Philippines, experiences a tropical monsoon climate with a distinct wet and dry season, characterized by significant annual rainfall averaging approximately 2,136

millimetres (84.1 inches). The wet season, spanning from May to November, contributes the bulk of the rainfall, with October being the wettest month, receiving an average of 262 millimetres (10.3 inches). In contrast, the dry season from December to April sees a marked reduction in precipitation, with February as the driest month, averaging just 69 millimetres (2.7 inches).

The municipality's climate is heavily influenced by the Southwest Monsoon (Habagat), which brings intense rains and occasional storms between June and September, and the Northeast Monsoon (Amihan), which delivers milder conditions from November to March. These climatic patterns, combined with the region's low-lying and varied elevation ranging from 4 to 204 meters above sea level, make Sofronio Española particularly vulnerable to flooding during prolonged rainfall events, especially in densely populated or agricultural areas. Understanding this annual rainfall distribution is critical for local water resource management, disaster preparedness, agricultural planning, and infrastructure development to mitigate the impacts of heavy rains and flooding (Weather and Climate, 2020)

Vegetation

The municipality is characterized by a diverse array of vegetation types, including natural forests, mangroves, and agricultural lands. In 2010, approximately 73% of the municipality's land area, equating to 24,800 hectares, was covered by natural forests. However, by 2020, the region experienced a loss of 202 hectares of natural forest, resulting in an estimated 129 kilotons of CO_2 emissions (Global Forest Watch). The coastal areas of Sofronio Española are notable for their mangrove forests, which play a crucial role in coastal protection and serve as vital habitats for various marine species. Despite their importance, these mangrove ecosystems have faced deforestation pressures. Between 1992 and 2014, the municipality experienced a net decrease of 645.03 hectares in mangrove forest extent, with significant deforestation recorded in areas such as Isumbo, Pinataray, and Labog.

The region's terrestrial vegetation is predominantly composed of lowland evergreen tropical rainforests, featuring species such as dao (Dracontomelon dao), Ipil (Intsia bijuga), and apitong (Dipterocarpus gracilis). These forests are part of the larger Palawan rainforests ecoregion, which is recognized for its high biodiversity and endemism. Agricultural activities have also shaped the landscape of Sofronio Española. Initiatives like the "Gulayan sa Barangay" project, launched by the Department of Agriculture in 2020, aim to enhance food production by supporting local vegetable growers. This program provides farming materials and establishes food terminals to facilitate the distribution of agricultural produce (Palawan News, 2020)

Run-off

There are 129 water resources in the municipality: 12 navigable rivers, 10 non- navigable rivers, 64 streams and creeks, 33 springs and 10 waterfalls. Of these, 61 are perennial water sources, consisting of 21 rivers, streams and creeks; 30 springs; and 10 waterfalls. Yet only 25 can be tapped as irrigation and potable water sources which include 6 rivers, 18 springs and 1 waterfall. In summer, their flows slow down after the monsoon.

The municipality's terrain, characterized by narrow mountain ranges and steep slopes, facilitates rapid water flow during heavy rainfall, leading to increased surface runoff. This runoff often carries sediments from upland areas to coastal zones, contributing to siltation along the coastline. Observations from the Diwata-1 microsatellite have identified sediment plumes near the coastal waters of Sofronio Española, indicating substantial sediment transport via surface runoff.

Additionally, agricultural activities in the area, such as plowing and tilling, can induce soil erosion, further increasing sediment loads in runoff. The application of fertilizers and pesticides may also lead to excess nutrients being transported to coastal waters through surface runoff, potentially impacting marine ecosystems. Understanding the dynamics of surface runoff in Sofronio Española is crucial for effective water resource management,

flood mitigation, and environmental conservation. Implementing sustainable land-use practices and enhancing vegetation cover can help reduce runoff velocity and sediment transport, thereby mitigating flooding and siltation issues in the municipality (Comprehensive Development Plan MPDO 2020–Sofronio Española, 2024)

Elevation

It features a diverse topography with elevations ranging from sea level to approximately 204 meters (669 feet) above mean sea level, with an average elevation of about 30 meters (98 feet). The municipal Center sits at an elevation of 16.5 meters (54.2 feet), while specific barangays display varied elevations, such as Iraray at 6.4 meters (21.0 feet), Abo-Abo at 4.5 meters (14.8 feet), Pulot Shore at 16 meters (52.5 feet), and Punang at 8 meters (26 feet). The highest point in the municipality reaches up to 139 meters (456 feet).

These elevation differences influence the area's climate, hydrology, and biodiversity, impacting local agriculture, water resource management, and flood susceptibility. The lower-lying areas are more prone to flooding, especially during heavy rains brought by the monsoon seasons, while upland regions are significant for forest cover and biodiversity conservation. This varied topography also shapes land use, with agricultural activities concentrated in the lowlands and natural forests and vegetation predominating in the upland areas (Philippine Atlas, 2013).

The Linear Aspect of the Pulot Watershed

The linear aspect of the drainage network such as stream order (Nu), bifurcation ratio (Rb), stream length (Lu) results have been shown in this table.

Table 2. Linear Aspect of Pulot Watershed (Pulot Integrated Watershed Management Plan, 2011)

Stream Order (u)	Number of Streams (Nu)	Stream Length kilometer (Lu)	Log (Nu)	Log Lu
1	13	47.315	1.113943	1.674999
2	4	4.332	0.60206	0.636688
3	2	12.818	0.30103	1.10782
4	1	5.314		0.725422
5	1	0.218		-0.66154
6	1	1.33		0.123854
7	1	0.702		-0.15366
8	1	17.284		1.237644
Total	**24**	**89.313**		

The table presents data on stream order, the number of streams (Nu), stream lengths (Lu), and their logarithmic values for a given watershed. The watershed's drainage network reveals a hierarchical organization, with the highest stream order being 8. Lower-order streams are the most numerous, with 13 first- order streams, while higher-order streams are fewer, with only one stream for orders 4 through 8. This pattern aligns with Horton's law of stream numbers, which statesthat the number of streams decreases geometrically with increasing order.

The total stream length is 89.313 km, with first-order streams contributing the most (47.315 km) due to their extensive branching. In contrast, higher-order streams generally have.

Year of Operation

The water supply challenges in Sofronio Española has a long history. The original water system, established in 1992, provided limited service, supplying water primarily to Barangay Pulot Center and a few households in Barangay Pulot Shore.

Many other communities relied on alternative sources, such as manual water pumps, deep wells and the community-based water projects initiated by various non- government

organizations. These solutions, while helpful, were insufficient to meet the growing demands of the municipality's expanding population shorter combined lengths, except for the 8th-order stream, which has a significant length of 7.284 km, indicating its dominance as the main-channel. The logarithmic values (log (Nu) and (log (Lu)) show a decreasing trend with higher stream orders, consistent with the reduction in stream numbers, though the stream lengths exhibit some variability. An anomaly is observed in the 5th-order stream, which has an unusually short length (0.218), potentially indicating local geological or anthropogenic influences. Overall, the watershed demonstrates a well-organized drainage network, with the main channel playing a crucial role in water conveyance, though localized deviations merit further investigation.

Recognizing the need for a more comprehensive solution, the Sofronio Española Local Government Unit (LGU), in collaboration with the Provincial Government of Palawan (PGP), launched the Sofronio Española Waterworks System in 2018. This initiative was designed to address the municipality's water supply needs on a larger scale. The municipal- wide operation of the water system began in October 2018, marking a significant milestone in improving access to clean and reliable water. Since then, the system has continuously operated, evolving to serve the growing population and playing a critical role in enhancing the quality of life for residents across Sofronio Española.

If the old water system, established in 1992, serves as the basis, it will be in operation for over 32 years as of 2024. On the other hand, if the current Sofronio Española Waterworks System, which began municipal-wide operations in October 2018, is the basis, it has been operating for 6 years up to the present.

Both timelines highlight the efforts to provide water access to the community, with the transition in 2018 marking a significant upgrade in scale and efficiency to meet the growing demands of Sofronio Española.

Table 3. The Seven Barangays in Sofronio Española with Active Water-metered Connection Year 2023 – Residential (Sofronio Espanola Supply Waterworks System,2023)

Barangay in Sofronio Española	Number of Household with Active Water-metered Connection
Iraray	436
Pulot Center	1,287
Pulot Shore	502
Pulot Interior	220
Punang	251
Labog	237
Panitian	157
Total	**3,090**

The population of Sofronio Española with active water meter connections across its barangays totals 3,090 individuals. Among these, Pulot Center has the highest number of connections, serving 1,287 people, which makes up 41.7% of the total population with active water meters. This indicates that Pulot Center likely has the highest population density or the most developed water infrastructure in the municipality. On the other hand, Panitian has the smallest number of connections, with only 157 residents with water connection, representing just 5.1% of the total.

Other barangays like Pulot Shore and Iraray have 502 and 436 people connected to the water system, respectively, accounting for 16.2% and 14.1% of the total population with active water meter connections.

In contrast, barangays such as Pulot Interior, Punang, Labog, and Panitian have relatively fewer connections, with populations ranging from 157 to 251 people. The distribution of active water connections suggests that

water infrastructure is more concentrated in the more urbanized or accessible barangays like Pulot Center, Pulot Shore, and Iraray.

Volume of Production

The system is composed of an independent water system sub-project to serve nine (9) barangays of the town. The table shows the annual volume production of the water system is 2,007,500 m^3, reflecting its operational capacity of 5,500 m^3 per day. This volume represents the total amount of freshwater water available for distribution each year, ensuring a reliable supply to meet the community's needs (Sofronio Espanola Waterworks System, 2023).

Table 4. Volume of Water Capacity in Sofronio Español (Sofronio Española Water Supply System, 2017)

Cubic Meter Per Day (m3day)	Cubic Meter Per Year(m3/yr)
5,500	2,007,500

Water production volume refers to the total amount of water generated or extracted from a specific source over a given period. It can include both natural water flow, such as rainfall or river discharge, and human-engineered systems like reservoirs or wells. The volume is typically measured in units such as litres, cubic meters, or gallons, depending on the scale of production. This metric is essential for understanding water availability and management in a region.

Total Volume of Household Water Footprint Based on Billed Water Consumption in Cubic Meter per Year (m3/year)

The total household water footprint reflects the volume of water consumed annually, as measured through billed water usage in cubic meters (m^3). This metric provides a clear indication of domestic water consumption patterns over time..

Table 5. Total Volume of Household Water Footprint Based on Billed Water Consumption in Cubic Meter per Year (m^3/year) (Sofronio Espanola Water Works System, 2023)

Year of Operation	Total Number of Consumer	Water footprint in Cubic Meter as to Domestic Use (m3/yr)
2011	742	106,392
2012	741	126,322
2013	778	114,221
2014	818	138,797
2015	878	170,244
2016	902	176,104
2017	939	199,112
2018	1,342	230,368
2019	1,967	328,440
2020	2,412	414,822
2021	2,592	493,411
2022	2,904	564,857
2023	3,090	702,664

The table shows from 2011 to 2023, the total number of consumers served by the water system increased from 742 to 3,090, representing a remarkable 316.5% growth over the 12-year period. This increase translates to an annual average growth rate (AAGR) of approximately 11.56% per year, indicating steady growth in the population relying on the system. The fastest annual growth occurred between 2018 and 2019, when the number of consumers rose from 1,342 to 1,967, a significant

46.6% increase in a single year, suggesting a period of rapid development or expansion of services.

Simultaneously, the water footprint for domestic use also exhibited a dramatic increase, rising from 106,392 m^3/year in 2011 to 702,664 m^3/year in 2023, a cumulative increase of 561%. The compound annual growth rate (CAGR) for water consumption over this period was approximately 15.77% per year, demonstrating a strong correlation between population growth and water demand. The largest year-on-year increase in water usage occurred between 2022 and 2023, with a jump of 24.4%, reflecting a significant surge in water demand during this period.

The relationship between the total number of consumers and water consumption shows a strong linear trend, with a Pearson correlation coefficient of nearly +1, indicating a near-perfect positive relationship. However, the.

Condition of Pulot Watershed

Assessing the underlying conditions of the Pulot Watershed requires a comprehensive approach that considers both environmental and social factors. The health of the watershed is critical not only for maintaining ecological balance but also for ensuring the well-being of the communities that rely on its resources.

Environmental factors, focusing on land cover the open and closed forest; play a significant role in the sustainability of the watershed. At the same time, social factors, including local population growth, community engagement, influence the watershed's management and conservation efforts. By examining both environmental and social aspects, the researcher can gain a deeper understanding of the Pulot Watershed's current state and identify strategies for its long-term preservation and sustainable use.

per capita water consumption reveals some interesting efficiency dynamics. In 2011, each consumer used an average of 143.4 m^3/year, which increased to 227.3 m^3/year by 2023, representing a 58.5% rise in per capita consumption over 12 years. This trend suggests that, in addition to population growth, individual water usage has also risen, possibly due to improved access to water, increased standards of living, or expanded domestic applications of water.

In conclusion, the data highlights the critical challenges of managing a rapidly increasing water demand driven by population growth and rising per capita consumption. As the water system expands, it is essential to implement strategies that ensure the sustainability of water resources, optimize consumption patterns, and maintain compliance with national standards for drinking water quality. This underscores the importance of continuous investment in infrastructure, water- saving technologies, and public awareness to balance demand with resource availability

Environmental Factors - Land Cover (Open and Closed Forest)

Watersheds play a critical role in managing water resources, influencing the availability and quality of water within ecosystems and for human consumption. Terrestrial forests, encompassing both closed and open forest types, significantly affect watershed dynamics. Closed forests, characterized by dense canopies that limit sunlight penetration, often contribute to reduced soil erosion, enhanced water infiltration, and moderated water flow. In contrast, open forests, with their sparser canopy cover, can have different impacts, such as increased surface runoff and higher susceptibility to soil degradation (Andrews Forest, 2023). Forest cover type, structure, and health are pivotal in determining hydrological processes like water filtration, sediment transport, and nutrient cycling within watersheds (MDPI, 2023). Effective forest and watershed management requires an understanding of how these interactions vary across landscapes, climates, and forest densities.

Terrestrial forests are among the key natural ecosystems that require urgent attention and conservation. These forests offer numerous essential services, including water filtration, air purification, erosion control, carbon sequestration, and climate regulation, among others. In this data, "terrestrial forests" refers to both "Closed Forest" and "Open Forest" land cover types, as well as the changes observed in these areas between 2005 and 2020.

Table 6. Total Terrestrial Forests of Sofronio Española per ECAN Zone (2005-2020) (Natural Capital Accounting- Sofronio Espanola PCSD, 2024)

Sofronio Española ECAN Zone	2005	2020	Net Change (Ha.)	% Change
Core Zone	3,621.71	3,494.54	-127.17	-4%
Buffer Zone	3,164.74	3,053.13	-111.61	-4%
Restricted Use Zone	116	95.12	-20.88	-18%
Controlled Use Zone	2,717.08	2,688.47	-28.61	-1%
Traditional Use Zone	331.66	269.54	-62.12	-19%
Multiple Use Zone	131.84	168.4	36.56	28%
TOTAL	**6,918.29**	**6,716.07**	**-202.22**	**-3%**

The table presents a summary of changes in the land area of the Environmental Critical Areas Network (ECAN) zones in Sofronio Española, Palawan, between 2005 and 2020. ECAN zoning is a framework used to manage and conserve ecological resources while supporting sustainable development. The data highlights the dynamic shifts in land use and conservation priorities across different ECAN zones over 15 years. Between 2005 and 2020, Sofronio Española experienced notable changes in its Environmental Critical Areas Network (ECAN) zones, reflecting shifting land use and conservation priorities.

The Core Zone, designated for strict ecological protection, saw a reduction of 127.17 hectares (4%), likely due to encroachments or reclassification, while the Buffer Zone, which protects the Core Zone from human impact, also decreased by 111.61 hectares (4%).

The Restricted Use Zone experienced the most significant proportional decline, losing 20.88 hectares (18%), potentially driven by increasing demands for resource extraction or settlement. Similarly, the Traditional Use Zone, supporting indigenous and community practices, decreased by 62.12 hectares (19%), indicating a possible decline in traditional land use and cultural practices.

The Controlled Use Zone, where regulated resource use is permitted, showed a modest decrease of 28.61 hectares (1%), suggesting relatively stable management.

In contrast, the Multiple Use Zone expanded by 36.56 hectares (28%), signalling increased economic activity and development. Overall, there was a net loss of 202.22 hectares (3%) across all ECAN zones, raising concerns about the erosion of ecological protection and cultural heritage due to land conversion and development pressures.

These changes highlight the need for strengthened conservation efforts, sustainable development practices, and support for local communities to balance ecological preservation with socio-economic growth.

Table 7. Disaggregated Forest Cover Change of Española vis-à-vis 2006 ECAN Zones. (Natural Capital Accounting- Sofronio Espanola -PCSD, 2024)

Sofronio Española ECAN Zone	Closed Forest Zone				Open Forest Zone			
	2005	2020	Net Change (Ha.)	% Change	2005	2020	Net Change (Ha.)	% Change
Core Zone	2,456.98	-	- 2,456.98	-100%	1,164.73	3,494.54	2,329.81	200%
Buffer Zone	2,598.81	-	- 2,598.81	-100%	565.93	3,053.13	2,487.20	439%
Restricted Use	96.4	-	-96.4	-100%	19.6	95.12	75.52	385%
Controlled Use	2,288.36	-	- 2,288.36	-100%	428.72	2,688.47	2,259.75	527%

Sofronio Española ECAN Zone	Closed Forest Zone				Open Forest Zone			
Traditional Use	214.05	-	-214.05	-100%	117.61	269.54	151.93	129%
Multiple Use Zone	48.62	-	-48.62	-100%	83.22	168.4	85.18	102%

The data illustrates significant forest cover changes in the Sofronio Española ECAN Zone between 2005 and 2020, marked by a total loss of closed forests and a dramatic expansion of open forests across all zones. These shifts highlight substantial environmental and ecological transitions, likely influenced by human activities and natural processes.

Core Zone

The Core Zone experienced a complete loss of closed forests, declining by 2,456.98 hectares (- 100%), while open forests surged by 2,329.81 hectares (200%). This dramatic shift indicates significant ecosystem alteration, potentially due to human encroachment or land-use changes in a zone traditionally expected to prioritize conservation

Buffer Zone

Like the Core Zone, the Buffer Zone saw a total loss of closed forests, decreasing by 2,598.81 hectares (-100%). Meanwhile, open forests increased by an astounding 2,487.20 hectares (439%), suggesting extensive fragmentation or reduced forest density due to activities like logging, settlement expansion, or agricultural use.

Restricted Use Zone

This zone, characterized by limited human activity, also experienced a complete loss of closed forests, with a reduction of 96.40 hectares (-100%). In contrast, open forests expanded by 75.52 hectares (385%), reflecting a transition from dense forest ecosystems to less intact forest conditions, potentially driven by regulated extraction or low-impact human activities.

Controlled Use Zone

The Controlled Use Zone witnessed a total closed forest loss of 2,288.36 hectares (-100%), with open forests increasing significantly by 2,259.75 hectares (527%). This suggests intensive land-use activities, likely aligned with regulated resource extraction or development projects that transitioned the zone from dense forest coverage to a more open landscape.

Traditional Use Zone

This zone saw a complete loss of closed forests, with a reduction of 214.05 hectares (-100%), and a moderate increase in open forests by 151.93 hectares (129%). This indicates a shift influenced by traditional land uses, such as small-scale agriculture or resource harvesting, resulting in reduced forest density.

Multiple Use Zone

The Multiple Use Zone lost all closed forests, declining by 48.62 hectares (-100%). However, open forests grew by 85.18 hectares (102%), reflecting a transformation consistent with the zone's designation for sustainable use, likely allowing mixed activities like farming and small-scale resource extraction.

The observed loss of closed forests and the significant expansion of open forests in the Sofronio Española ECAN Zone have critical implications for the region's watershed. Forest ecosystems play a vital role in regulating hydrological processes, maintaining water quality, and supporting soil stability. The transition to open forests reduces water retention capacity, increasing surface runoff and decreasing groundwater recharge, which can exacerbate seasonal water scarcity (Chapin et al., 2011).

Additionally, the loss of dense canopy cover exposes soil to erosion, leading to higher sedimentation rates in rivers and streams, which adversely affects aquatic ecosystems and water quality (Dudley & Stolton, 2003). Open forests are less effective at filtering pollutants, further degrading water resources and increasing the risk of contamination from agricultural runoff

and other sources (Ellison, Futter, & Bishop, 2012). Altered streamflow patterns, with more intense floods during rainy periods and diminished flows in dry seasons, threaten agricultural productivity and water supply systems.

Moreover, forest loss undermines biodiversity and ecosystem functionality, which are critical for sustaining watershed health and climate regulation (Malmer, 2007). Addressing these issues requires urgent reforestation efforts, sustainable land-use policies, and integrated watershed management strategies to mitigate the adverse impacts on water resources and ecological stability in Sofronio Española.

Table 8. Disaggregated Forest Cover Change Analysis pe Barangay (Natural Capital Accounting-Sofronio Espanola PCSD, 2024)

Barangay	**Core Zone**				**Buffer Zone**			
	2005	2020	Net Chang e	% Change	2005	2020	Net Change	% Change
Abo-abo	0	0	0	-	0	0	0	-
Iraray	0	0	0	-	0	0	0	-
Isumbo	255.03	240.18	-14.85	-6%	65.14	113.36	48.23	74%
Labog	373.62	472.51	98.89	26%	9.77	318.47	308.7	3159%
Panitian	602.32	561.38	-40.94	-7%	35.99	59.02	23.03	64%
Pulot Center	0	0	0	-	0	0	0	-
Pulot Interior	795.52	826.79	31.276	4%	1,712.82	1,573.09	-139.72	-8%
Pulot Shore	0	0	0	-	2.98	0	-2.98	-100%
Punang	1,592.20	1,393.63	-198.56	-12%	1,197.34	989.06	-208.28	-17%

The table provides an analysis of changes in land area for different barangays (villages or districts) in terms of their Core Zone and Buffer Zone between 2005 and 2020. The Core Zone, which represents protected or central areas, showed varying trends. Some barangays experienced significant changes, while others remained unchanged. Notable increases include Labog, with a 26% rise (98.89 hectares), while Punang showed the largest decrease, losing 12% (-198.56 hectares). Panitian also saw a decrease of 7% (-40.94 hectares). Meanwhile, barangays like Abo-abo, Iraray, Pulot Center, and Pulot Shore had no core zones recorded in either year.

For the Buffer Zone, which surrounds core zones and often allows for more flexible usage, several barangays experienced remarkable changes. Labog's buffer zone expanded drastically by 3,159% (308.7 hectares), indicating possible reclassification or policy changes. Pulot Shore, however, saw a complete removal of its buffer zone (-100%), while Pulot Interior experienced an 8% reduction (-139.72 hectares). Isumbo and Panitian saw substantial increases of 74% and 64%, respectively. On the other hand, Punang experienced the largest decrease in absolute terms, with a loss of 208.28 hectares (-17%). These changes reflect evolving land-use dynamics and possible shifts in conservation or development priorities. Some barangays, such as Abo-abo, Iraray, and Pulot Center, displayed no recorded changes, potentially indicating stability in land designation or absence.

The dramatic expansion of Labog's buffer zone (+3,159%) suggests significant policy shifts, while the complete removal of Pulot Shore's buffer zone (-100%) may point to reclassification or urbanization. Overall, this data highlights varying trends in land management, with some areas expanding their protected zones and others seeing reductions due to possible reclassification, human activity, or policy changes.

Social Factors- Population Growth and Water Demand

Population growth and increasing water demand are among the most pressing social factors influencing resource management and sustainability today. As populations expand, the strain on water resources intensifies, driven by the need to meet domestic, agricultural, industrial, and energy production demands. Rapid urbanization, coupled with rising living standards, further amplifies water consumption, placing additional pressure on already limited freshwater supplies.

These challenges are compounded by unequal distribution of resources, inefficient usage, and climate variability, which exacerbate water scarcity in many regions. Addressing the interconnection between population dynamics and water demand is critical for ensuring equitable access to water, promoting sustainable development, and safeguarding the resilience of ecosystems in the face of global environmental change.

Table 9. Disaggregated Forest Cover Change Analysis per Barangay (Natural Capital Accounting-Sofronio Espanola PCSD, 2024)

Barangay	Core Zone				Buffer Zone			
	2005	2020	Net Change	% Change	2005	2020	Net Change	% Change
Abo-abo	0	0	0	-	0	0	0	-
Iraray	0	0	0	-	0	0	0	-
Isumbo	255.03	240.18	-14.85	-6%	65.14	113.36	48.23	74%
Labog	373.62	472.51	98.89	26%	9.77	318.47	308.7	3159%
Panitian	602.32	561.38	-40.94	-7%	35.99	59.02	23.03	64%
Pulot Center	0	0	0	-	0	0	0	-
Pulot Interior	795.52	826.79	31.276	4%	1,712.82	1,573.09	-139.72	-8%
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Table 10. Population and Density of the Municipality of Sofronio Española (2010–2020)

Baranga y	Pop % (2020)	Pop (2010)	Pop (2015)	Pop (2020)	Chang e (2015-2020)	Annual Pop Growth Rate (2015-2020)	Area (Has)	Area (Sq. Km)	Pop Den'ty / sq.m 2010	Pop Den'ty // sq.m 2015	Pop Den'ty / sq.m 2020
Abo-abo	8.12%	2421	2,596	3,037	16.99 %	3.36%	1,375	13.75	176	189	221
Iraray	8.52%	2916	2,925	3,186	8.92%	1.82%	2732	27.32	107	107	117
Isumbo	6.57%	2159	2,127	2,457	15.51 %	3.08%	3,390	33.90	64	63	72
Labog	11.21%	3042	3,534	4,194	18.68 %	3.67%	7,981	79.81	38	44	53
Panitian	16.54%	4878	5,274	6,187	17.31 %	3.42%	7,402	74.02	66	71	84
Pulot Center	19.13%	5713	5,789	7,159	23.67 %	4.57%	2,597	25.97	220	223	276
Pulot Interior	8.33%	2097	3,060	3,116	1.83%	0.38%	7,235	72.35	29	42	43
Pulot Shore	13.26%	4264	4,523	4,960	9.66%	1.96%	1,842	18.42	231	246	269
Punang	8.34%	2507	3,048	3,120	2.36%	0.49%	9,101	91.01	28	33	34
Abo-Abo dispute to Narra							84				
Calasagu en dis-pute to Brooke's Point							5878				

Source: Philippine Statistics Authority, 2020 Census of Population MPDOCalculation

The population and density data for Sofronio Española from 2010 to 2020 reveal significant disparities among barangays in terms of growth and land use. Pulot Center stands out as the most populous barangay, accounting for 19.13% of the total population in 2020, with a high annual growth rate of 4.57% and a density increase from 220 to 276 persons per square kilometre.

Similarly, Pulot Shore is highly dense, with 269 persons per square kilometre in 2020, reflecting its accessibility and development. In contrast, barangays like Punang and Pulot Interior exhibit slower growth, with minimal annual increases of 0.49% and 0.38%, respectively, and remain sparsely populated, with densities of 34 and 43 persons per square kilometre in 2020. Abo-abo, Iraray, Isumbo, and Labog show moderate growth and density increases, while Panitian experienced steady growth at 3.42% annually, reaching a density of 84 persons per square kilometre.

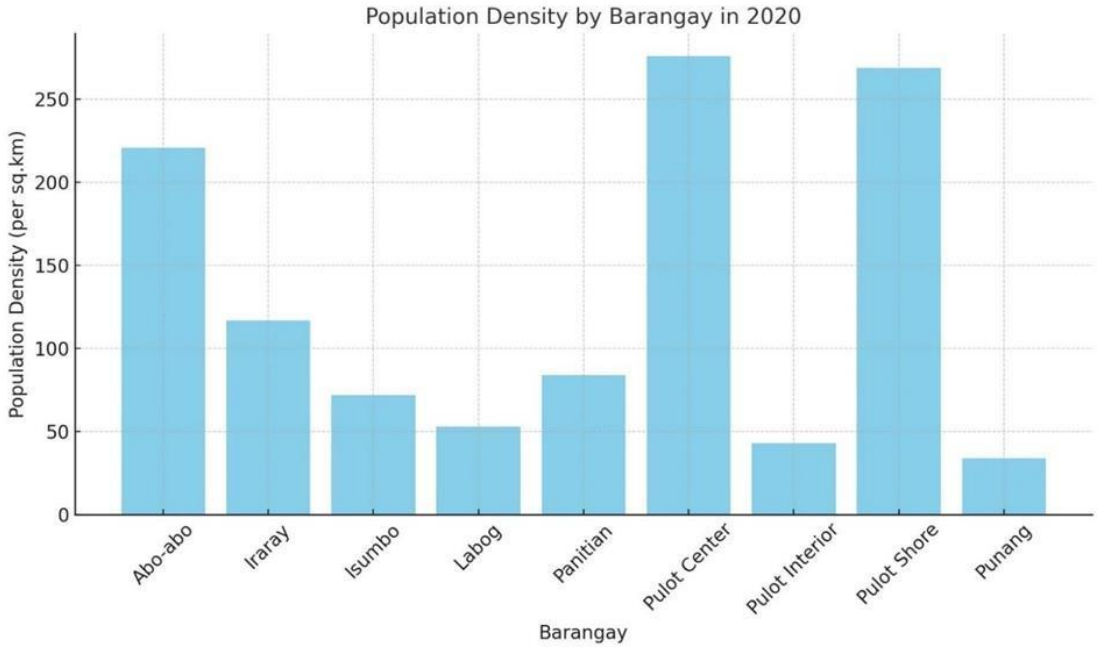

Figure 2. Population Density of Sofronio Espanola Year 2020

The bar graph depicts the population density of Sofronio Española's barangays in 2020, revealing significant disparities across the municipality. Pulot Center and Pulot Shore emerge as the most densely populated barangays, each surpassing 250 persons per square kilometre, reflecting their urbanized or central roles with concentrated populations. On the other hand, Punang and Pulot Interior have the lowest densities, with fewer than 50 persons per square kilometre, indicating rural characteristics and larger land areas relative to their populations.

To analyse this data, statistical tools such as descriptive statistics were used to calculate the mean, median, and range, providing a clear picture of the overall distribution of densities. Variance and standard deviation quantified the variability among barangays, highlighting significant differences in population distribution. Ranking analysis identified the barangays with the highest and lowest densities, aiding in prioritizing resource allocation and infrastructure development.

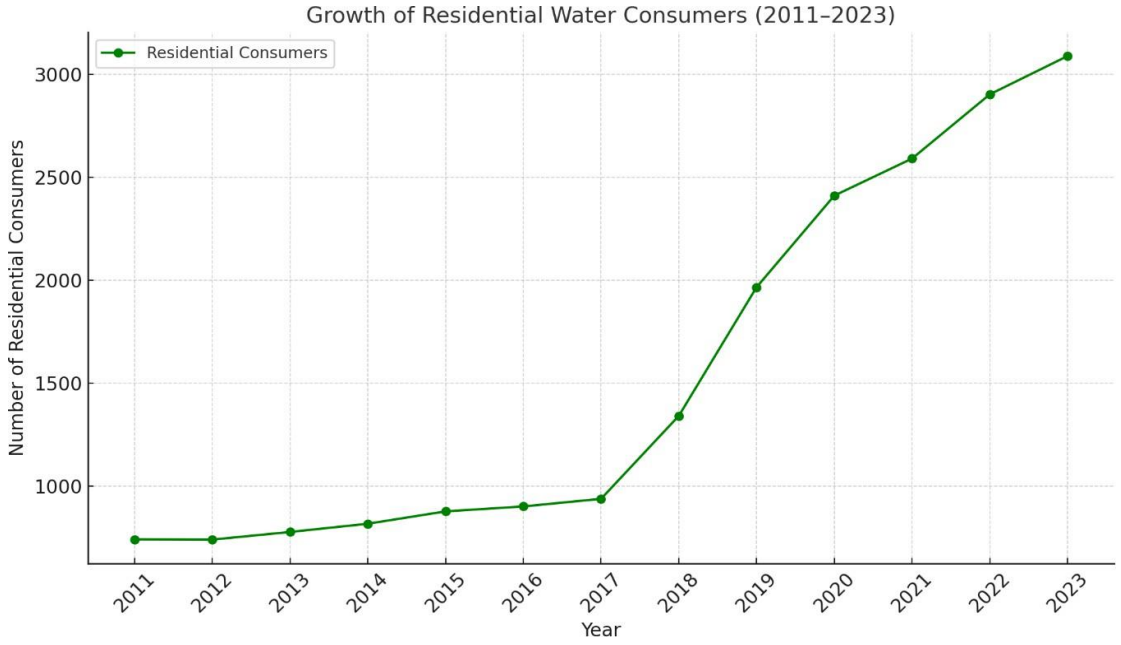

Figure 3. Population Density of Sofronio Espanola Year 2020

The line graph depicts the growth of residential water consumers in Sofronio Española from 2011 to 2023, showcasing both gradual and significant increases over time. The data reveals a steady rise in consumer numbers from 2011 to 2017, followed by an accelerated growth beginning in 2018, reaching 3,090 consumers in 2023. This trend reflects increased access to water services, population growth, and improvements in infrastructure.

Statistical tools such as trend analysis were employed to identify the overall pattern of growth over the years. The graph uses time- series plotting, which is effective for visualizing changes over a continuous period.

The graph illustrates a steady increase in the number of residential water consumers from 2011 to 2023, reflecting a remarkable expansion of the water system. The total number of consumers grew from fewer than 800 in 2011 to over 3,000 in 2023, demonstrating significant progress in providing water services. Between 2011 and 2017, the growth was relatively slow and linear, suggesting limited expansions or a gradual uptake of water services during these years. However, a significant spike occurred between 2018 and 2019, marking the fastest annual growth. This sharp rise likely reflects major developments such as new infrastructure, urbanization, or an increasing population in serviced areas. From 2020 to 2023, growth continued steadily but at a slower pace compared to 2018–2019, indicating that the system may have reached a more stable rate of expansion.

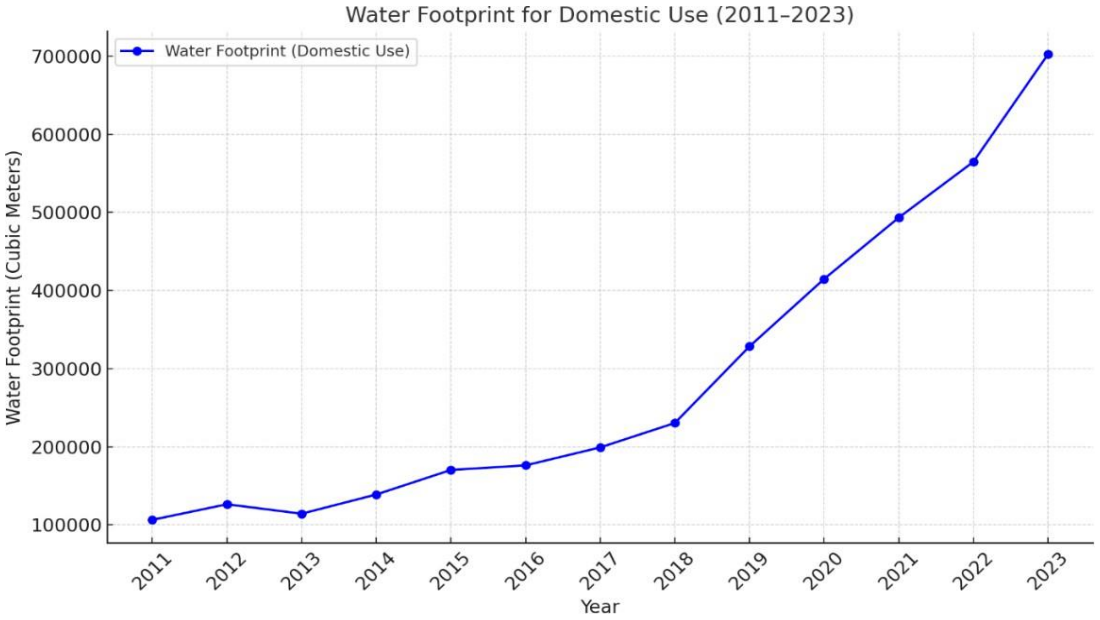

Figure 4. Water Footprint for Domestic Use from Year 2011-2023

The graph illustrates the trend of the water footprint for domestic use from 2011 to 2023, measured in cubic meters. The data reveal a consistent upward trajectory, with the water footprint increasing significantly over the 12- year period. The growth appears to follow an exponential pattern, with notable accelerations starting around 2018 and peaking in 2023.

From a statistical perspective, the early years (2011–2016) exhibit relatively modest increases, suggesting a gradual growth phase. However, after 2017, the growth rate intensifies sharply, as seen in the steeper slope of the curve. By 2023, the water footprint surpasses 700,000 cubic meters, reflecting a substantial increase compared to the baseline in 2011, which was close to 100,000 cubic meters. The sharp rise in the latter years could be analysed further through regression analysis to quantify the growth rate and assess the relationship between time and the water footprint. A time-series analysis could also identify any underlying seasonal or periodic trends that contribute to this acceleration.

The variability in the annual increases might indicate external factors such as population growth, changes in water consumption behaviour, or policy shifts affecting water use. In summary, the data underscore a significant and accelerating increase in the water footprint for domestic use over the examined period, emphasizing the importance of sustainable water management practices to address the growing demand.

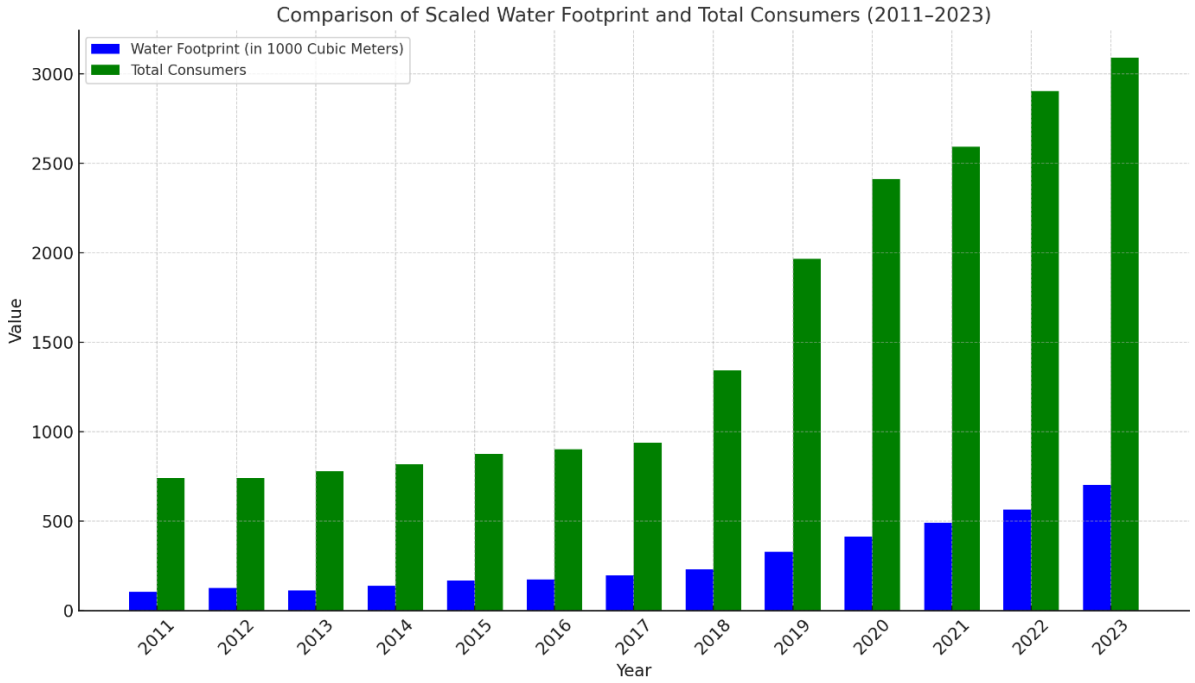

Figure 5. Comparison of Water Footprint and Total Consumer from Year 2011-2023

The bar graph illustrates the comparison between the scaled water footprint (in thousands of cubic meters) and the total number of consumers in Sofronio Española from 2011 to 2023. The graph demonstrates a steady increase in both metrics, with the water footprint rising from 106,392 cubic meters in 2011 to 702,664 cubic meters in 2023, while the number of consumers grew from 742 to 3,090 during the same period. Scaling the water footprint allows for a clearer visual comparison, revealing a parallel upward trend between the two components. Statistical analysis highlights that the water footprint increased more rapidly than the number of consumers, indicating higher per capita water consumption over time. A strong positive correlation between consumer growth and water demand is evident, suggesting that the rising population is a significant driver of increased water usage. Furthermore, percent change analysis shows that the water footprint grew by over 500%, while the consumer count quadrupled, emphasizing a disproportionate rise in water demand relative to population growth. These trends underscore the need for sustainable water resource management and infrastructure planning to meet the growing consumption demands of a rising population.

Using the same data, various scenarios were modeled to analyze the potential impacts of population growth and water consumption patterns. Each scenario explores the interplay between the increasing number of consumers and the water footprint under different assumptions in year 2050.

Scenario 1. Forecasting Consumer Growth and Water Footprint in Year 2050

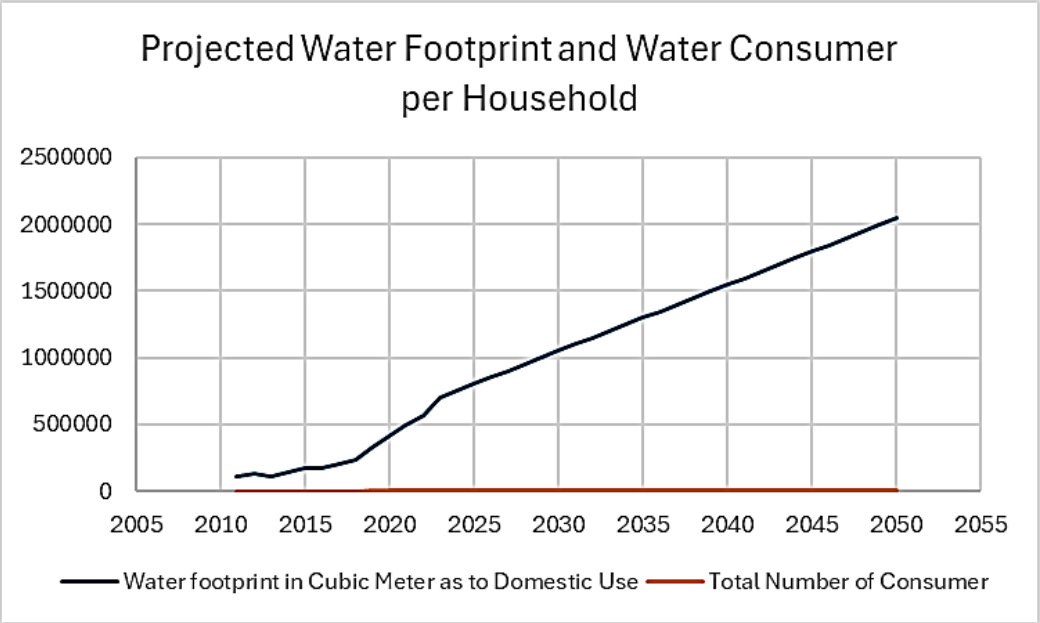

Figure 6. Projected Graph of Consumer Growth and Water Footprint in Year 2050

The analysis of the data reveals significant growth in both the water footprint and the total number of consumers from 2011 to 2050. The water footprint, starting at 106,392 cubic meters in 2011, is projected to grow to 2,044,276 cubic meters by 2050, representing a 19.2-fold increase over the 40-year period. This growth is not linear but steadily increases, driven by both population growth and rising per capita water consumption. Similarly, the total number of consumers is expected to rise from 742 in 2011 to 8,373 in 2050, reflecting an 11.3-fold increase. The consumer count grows at a near-linear rate, indicating a direct relationship between population expansion and water demand.

Statistically, the Compound Annual Growth Rate (CAGR) for the water footprint is calculated at 6.43%, while for the total number of consumers, it is slightly lower at 5.88%. The faster growth of the water footprint compared to the consumer count suggests an increase in per capita water usage, likely due to improved living standards, urbanization, and potentially less efficient water use. Using the Rule of 70, the doubling time for the water footprint is approximately 10.9 years, while for the total consumers, it is about 11.9 years, indicating that water demand is growing slightly faster than the population.

Key insights from this analysis highlight the divergence between the water footprint and the number of consumers, driven by increased household consumption and potential inefficiencies in water use. This trend poses significant sustainability challenges, with the projected water demand exceeding 2 million cubic meters by 2050. If water supply does not grow proportionately, this could result in severe water scarcity. Per capita water usage, calculated at 143.4 cubic meters per person in 2011, is expected to increase to 244.0 cubic meters per person by 2050, representing a 70.1% rise over the period, further compounding the demand.

To address these challenges, investment in water infrastructure, such as reservoirs and desalination plants, is essential. Public education campaigns and the adoption of water-saving technologies can help curb per capita usage. Additionally, governments and organizations need to develop long-term strategies for managing the growing gap between water supply and demand. Encouraging the use of water- efficient appliances and improving urban water distribution systems will also be critical. Without intervention, the exponential

growth in water demand, outpacing consumer growth, could lead to unsustainable water consumption levels by 2050. Therefore, efforts to increase water supply and improve efficiency are crucial for sustainable water resource management.

Scenario 2. Forecasting Water Footprint and Household Consumer Population at Constant Water Production of 2,007,500 cubic meter per year in year 2050

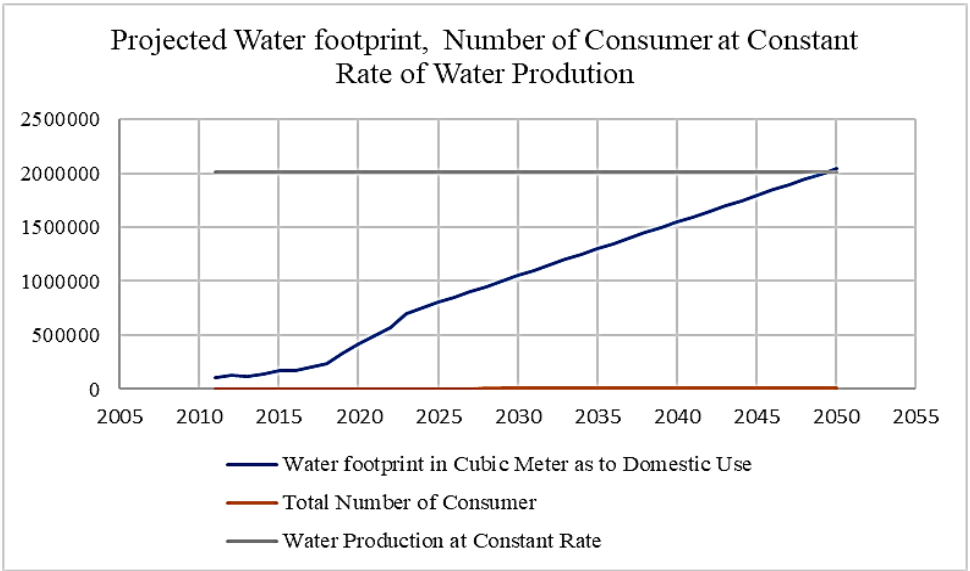

Figure 7. Projected Water Footprint and Consumer Growth with Same Water Production

This dataset forecasts the water footprint, total number of consumers, and compares these projections to a constant water production rate from 2011 to 2050. The water footprint, representing domestic water use, starts at 106,392 cubic meters in 2011 and grows to 2,044,276 cubic meters by 2050, marking a 19.2-fold increase over 40 years.

The compound annual growth rate (CAGR) for the water footprint is approximately 6.43%, demonstrating a rapid rise in water demand driven by population growth and increased per capita usage. Similarly, the total number of consumers grows from 742 in 2011 to 8,373 in 2050, representing an 11.3-fold increase with a CAGR of 5.88%. This steady growth in the consumer base highlights population expansion as a key driver of rising water demand. However, water production is held constant at 2,007,500 cubic meters throughout the period. While initially sufficient, this constant production rate becomes inadequate as water consumption surpasses production by 2045 signaling a looming water shortage. A closer comparison of growth rates reveals that the water footprint grows slightly faster than the consumer count, reflecting an increase in per capita water usage over time. In 2011, per capita usage was approximately 143.4 cubic meters per person, rising to 244.0 cubic meters per person in 2050, a 70.1% increase.

This trend indicates changing consumption patterns, urbanization, and the adoption of modern lifestyles. By 2045, the water footprint surpasses the constant production rate, and by 2050, the water footprint exceeds production by 36,776 cubic meters, underscoring an unsustainable trajectory. Statistical analysis reveals important insights into these trends.

Using the Rule of 70, the water footprint doubles every 10.9 years, while the total consumer base doubles every 11.9 years.

The exponential growth of the water footprint, compared to the more linear growth in the number of consumers, emphasizes the widening gap between demand and supply. This growing disparity signals a critical sustainability challenge, exacerbated by increasing per capita consumption.

The projected demand for over 2 million cubic meters of water by 2050 highlights the mounting pressure on water resources. The constant production rate is insufficient to accommodate this exponential growth, creating a critical need for resource management. Without intervention, the gap between supply and demand will widen, posing significant risks of water shortages.

Addressing this challenge requires investments in new infrastructure, such as desalination plants and reservoirs, as well as technologies that enhance water production and efficiency. Demand management strategies, including public education campaigns and policies promoting water-efficient appliances, are essential to curb consumption. Long-term policy planning is crucial to ensure sustainable water usage and equitable distribution, aligning production rates with rising demand.

In conclusion, the data highlights a growing water crisis driven by exponential increases in demand against a constant supply. While the consumer base expands steadily, rising per capita consumption accelerates water demand, outpacing production by 2045.

Without immediate investments in infrastructure, efficiency improvements, and conservation measures, water shortages could become a critical challenge by 2050. Proactive measures are essential to manage resources sustainably and prevent future crises.

Scenario 3: Incremental Increase in Water Production

Description: Water production grows by 1% annually, starting from 2023. By 2050, water production reaches aproximately 2,875,000 cubic meters aligning with increasing demand.

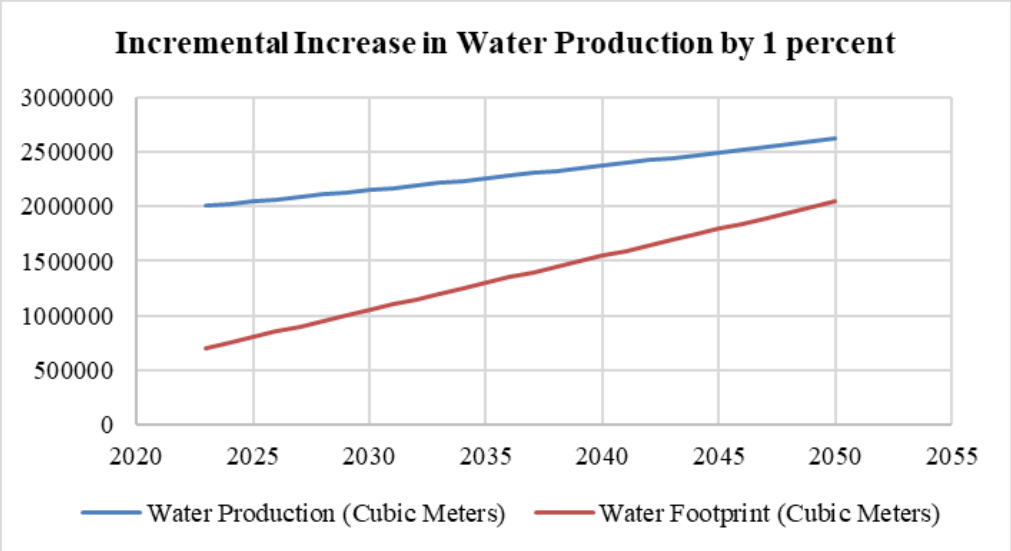

Figure 8. Incremental Increase in Water Production by One Percent

The graph illustrates water production with a 1% annual growth rate (yellow line with circles) and the forecasted water footprint (orange line with squares). Water production begins at 2,007,500 cubic meters in 2023 and rises steadily to approximately 2,875,000 cubic meters by 2050, e suring supply aligns with the

increasing demand. The water footprint, driven by population growth and rising per capita usage, grows from 702,664 cubic meters in 2023 to 2,044,276 cubic meters in 2050. Throughout the forecasted period, water production remains consistently higher than the water footprint, with the gap widening to about 830,724 cubic meters by 2050. This demonstrates that incremental production growth successfully prevents a supply deficit. Statistically, water production grows at a compound annual growth rate (CAGR) of 1%, while the water footprint grows at a higher CAGR of 6.43%, reflecting population growth and increasing per capita consumption. In 2023, water production exceeds demand by 1,304,836 cubic meters, and by 2050, production surpasses the water footprint by ~830,724 cubic meters. Key milestones include 2035, when the water footprint reaches approximately 1,300,000 cubic meters, still below production levels, and 2050, when water production increases by ~867,500 cubic meters compared to 2023, meeting the growing demand.

This scenario achieves sustainability by maintaining a surplus between supply and demand, ensuring the water needs of a growing consumer base of 8,373 people in 2050 are adequately supported.

To achieve the 1% growth, investments in desalination plants, reservoirs, and recycling systems are essential. However, while this scenario demonstrates effective resource management, it also raises environmental concerns regarding the energy usage and emissions associated with increased production.

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Scenario 4: Combined Crises (Population Boom + Climate Change)

Assumptions: Population grows faster than expected, and climate change exacerbates water demand. Per capita consumption rises while the total number of consumers increases beyond projections.

Outcome: By 2050, water demand exceeds 3,500,000 cubic meters, resulting in widespread water shortages, economic instability, and a potential humanitarian crisis.

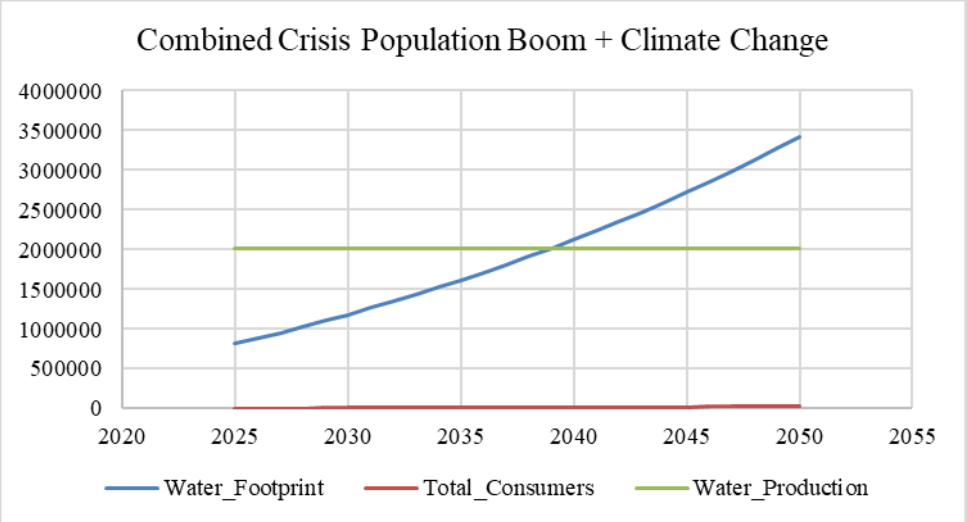

Figure 9. Combine Crisis (Population Boom Plus Climate Change)

The data illustrates the projected growth of water demand under the "Combined Crises Scenario," driven by accelerated population growth and increased per capita water consumption. Between 2025 and 2050, the water footprint grows exponentially, starting at 818,083.86 cubic meters in 2025 and reaching 3,420,928.49 cubic meters in 2050, far surpassing the constant water production rate of 2,007,500 cubic meters. This significant gap between demand and supply highlights

the potential for widespread water shortages and socio-economic instability.

The exponential growth in water footprint is driven by two compounding factors: a 5% annual increase in total consumers and a 2% annual rise in per capita water consumption starting from 2025. These statistical assumptions are modeled using growth equations for population and consumption, allowing for precise forecasting. For instance, the total number of consumers grows from 3,655.05 in 2025 to 29,771.65 in 2050, demonstrating a nearly tenfold increase in demand on water resources.

Statistical tools such as exponential growth modelling were employed to project water consumption trends and evaluate the sustainability of current production levels. These methods effectively illustrate how small annual growth rates, when compounded over decades, result in unsustainable resource demands. The constant production rate of 2,007,500 cubic meters highlights the inability of the system to accommodate rising demand, with shortages beginning as early as 2039, when demand exceeds supply at 2,015,697.59 cubic meters. This analysis underscores the importance of proactive resource management strategies, including water conservation policies, technological innovation, and sustainable population growth measures. Without significant interventions, the mismatch between supply and demand could lead to severe humanitarian and environmental consequences by 2050. Statistical modeling provides a robust framework for understanding the urgency of this issue and for guiding informed decision-making.

Social Awareness and Perception Towards Watershed Conservation and Management

The condition of the environment should not be the only focus; it is also essential to consider whether people are aware of the watershed from which their water is sourced.

This research was conducted not only to take into account what is happening in the surroundings but also to include people's awareness of where their water comes from. The data provided should reflect this perspective.

Table 11. Demographic Profile of the Respondent

Profile of Respondents	Category	Counts	% of Total
Age Group	18-24	74	20.9
	25-34	82	23.2
	35-44	94	26.6
	45-54	104	29.4
Sex	Male	140	39.5
	Female	214	60.5

The demographic profile of respondents reveals, with the largest proportion belonging to the 45-54 years age group, accounting for 29.4% of the total respondents. This is followed by the 35-44 years group, which represents 26.6%, and the 25-34 years group at 23.2%. The smallest group is the 18-24 years category, comprising 20.9% of the respondents. The data indicates a gradual increase in representation from younger to older age groups, peaking among individuals aged 45-54 years, suggesting that the survey is most representative of older middle-aged individuals.

In terms of sex, 60.5% of respondents are female, while 39.5% are male, highlighting a skew toward female representation. This suggests that nearly three out of five respondents are female, which may influence the overall findings by reflecting their perspectives more prominently.

Overall, the data indicates that older adults and females are more engaged or accessible in this survey, shaping the demographic composition of the respondents.

Table 12. Household Information of Respondents

Household Information	Category	Counts	% of Total
Number of Residents in Household	1-2	67	18.9
	3-4	71	20.1
	5 or more	216	61
Type of Residence	Boarding House	48	13.56
	Apartment	3	0.85
	Family Home	293	82.77
	Other	10	2.82

The analysis of household information, using frequency distributions and percentages, provides insights into the number of residents per household and the type of residence of the respondents. For the number of residents per household, most households fall into the category of 5 or more residents, representing 61.0% of the total respondents. Households with 3-4 residents account for 20.1%, while those with 1-2 residents make up 18.9%. These figures indicate that larger households are the most common, comprising most of the population surveyed.

For the type of residence, the analysis reveals that 82.77% of respondents live in family homes, making this the dominant residence type. Other types of residence, such as boarding houses (13.56%), apartments (0.85%), and other arrangements (2.82%), are much less common.

Table 13. Average Monthly Bill of Water Consumer Year 2024 (Residential)

Average Monthly Bill (Range)	*f*	Percentage	Rank
P100- P300	146	41.24	1
P301-P500	91	25.71	2
P501-P700	52	14.69	3
P701-P900	38	10.73	4
P901-P1,100	18	5.08	5
More than 1,100	9	2.54	6

The data reveals the distribution of average monthly bills across various ranges, highlighting the prevalence of certain billing patterns. The majority of monthly bills (41.24%) fall within the range of P100 to P300, making it the most common. This is followed by bills in the range of P301 to P500, which account for 25.71%, indicating that a significant portion of individuals have bills below P500. Moderate billing levels are observed in the ranges of P501 to P700 and P701 to P900, representing 14.69% and 10.73% of the total, respectively. Higher monthly bills, such as P901 to P1,100 and amounts exceeding P1,100, are less common, comprising only 5.08% and 2.54% of the data, respectively.

The ranking underscores this trend, with lower bill ranges being the most frequent and higher bill ranges significantly less so. This distribution suggests that most individuals experience relatively low monthly bills, reflecting affordability constraints or consumption patterns skewed toward lower expenditures.

Table 14. General Awareness on Watershed

Questions	Yes (*f*)	Yes (%)	No (*f*)	No (%)	Unsure (*f*)	Unsure (%)	Total
Do you know what a watershed is?	75	21.25	273	77.34	5	1.416431	353
Have you experienced water shortage during summertime?	277	80.06	55	15.9	14	4.046243	346
Have you experienced low water pressure in any season?	301	85.03	44	12.43	9	2.542373	354
Do you know how many watersheds we have in our municipality?	51	14.53	291	82.91	9	2.564103	351

The analysis of the questionnaire responses highlights key trends related to watershed knowledge and water-related experiences. Using descriptive statistics, such as frequency counts, percentages, and totals, the data provides a clear summary of the respondents' awareness and experiences. For the question, "Do you know what a watershed is?", only 21.25% of respondents answered "Yes," while a significant 77.34% answered "No," and 1.42% were "Unsure." This indicates limited awareness of watersheds among the population.

Regarding "Have you experienced water shortages during summertime?", the majority (80.06%) of respondents reported "Yes," suggesting that water shortages are a common issue. Only 15.90% of respondents answered "No," and 4.05% were "Unsure." When asked, "Have you experienced low water pressure in any season?", a large majority (85.03%) responded "Yes," while 12.43% said "No," and 2.54% were "Unsure." This underscores the prevalence of water pressure issues across the surveyed population.

Finally, for the question, "Do you know how many watersheds we have in our municipality?", only 14.53% answered "Yes," while 82.91% answered "No," and 2.56% were "Unsure." This highlights a significant lack of knowledge about local watersheds. These statistics reveal significant gaps in watershed knowledge and highlight widespread experiences of water-related issues, such as shortages and low pressure, among respondents. These findings suggest the need for targeted awareness campaigns and infrastructural improvements to address these challen.

Table 15. Perception on Watershed Importance

	Questions	Strongly Disagree	Strongly Disagree (%)	Disagree	Disagree (%)	Neutral	Neutral (%)	Agree	Agree (%)	Strongly Agree	Strongly Agree (%)	Total
1.	I believe that watershed conservation is crucial for community well-being.	0	0.00	0	0.00	23	6.50	29	8.19	302	85.31	354
2.	I feel informed about local watershed efforts.	196	55.37	104	29.38	42	11.86	7	1.98	5	1.41	354
3.	I actively participate in local	291	82.67	34	9.66	15	4.26	3	0.85	9	2.56	352

	Questions	Strongly Disagree	Strongly Disagree (%)	Disagree	Disagree (%)	Neutral	Neutral (%)	Agree	Agree (%)	Strongly Agree	Strongly Agree (%)	Total
	conservation initiatives											
4.	I believe that the government should invest more in watershed conservation	0	0.00	0	0.00	29	8.19	67	18.93	258	72.88	354
5.	I think that education about watersheds should be improved in school.	0	0.00	0	0.00	3	0.85	91	25.71	260	73.45	354
6.	I am concerned about pollution affecting the local watershed.	0	0.00	0	0.00	21	5.90	89	25.00	246	69.10	356
7.	I feel that the community is doing enough to protect our watersheds.	231	65.44	75	21.25	16	4.53	19	5.38	12	3.40	353
8.	I regularly seek out information on watershed conservation practices	329	92.42	18	5.06	5	1.40	3	0.84	1	0.28	356
9.	I believe that climate change significantly impacts local watersheds	0	0.00	2	0.58	7	2.02	21	6.07	316	91.33	346
10.	I think local government should prioritize watershed conservation.	0	0.00	0	0.00	5	1.46	44	12.87	293	85.67	342
11.	I believe that adequate local funding is necessary for effective watershed conservation initiatives.	0	0.00	0	0.00	0	0.00	75	21.87	268	78.13	343
12.	I believe that urban development poses a significant risk to the local watershed.	0	0.00	1	0.28	1	0.28	26	7.32	327	92.11	355

	Questions	Strongly Disagree	Strongly Disagree (%)	Disagree	Disagree (%)	Neutral	Neutral (%)	Agree	Agree (%)	Strongly Agree	Strongly Agree (%)	Total
13.	I think promoting sustainable agriculture practices can help protect the watershed	0	0.00	0	0.00	5	1.43	81	23.14	264	75.43	350
14.	I feel that there should be stricter regulations on industries that pollute waterways	1	0.29	3	0.87	8	2.31	93	26.88	241	69.65	346
15.	I think that collaboration among local governments, NGOs and citizens is essential for successful watershed conservation.	2	0.58	2	0.58	6	1.73	105	30.26	232	66.86	347

The analysis of the guided questions reveals significant insights into respondents' perceptions and actions regarding watershed conservation. Using descriptive statistics, including frequency counts, percentages, and totals, the data provides a detailed understanding of their beliefs and behaviours. For the statement, "I believe that watershed conservation is crucial for community well-being," an overwhelming 85.31% of respondents strongly agreed, while 8.19% agreed, and 6.50% were neutral. None of the respondents disagreed or strongly disagreed, emphasizing a strong consensus about the importance of watershed conservation.

Regarding "I feel informed about local watershed efforts," the majority, 55.37%, strongly disagreed, with 29.38% disagreeing, indicating a significant lack of awareness. Only 1.98% agreed, and 1.41% strongly agreed, while 11.86% remained neutral. This suggests a critical gap in knowledge and communication about local watershed initiatives.

For the question, "I actively participate in local conservation initiatives," a striking 82.67% strongly disagreed, and 9.66% disagreed, indicating minimal active participation. Only 0.85% agreed, and 2.56% strongly agreed, while 4.26% were neutral. This highlights a lack of community engagement in conservation efforts.

When asked, "I believe that the government should invest more in watershed conservation," 72.88% strongly agreed, and 18.93% agreed, reflecting strong support for increased governmental investment. Only 8.19% were neutral, with no respondents disagreeing or strongly disagreeing.

The statement, "I think that education about watersheds should be improved in school," garnered strong support, with 73.45% strongly agreeing and 25.71% agreeing. Neutral responses accounted for only 0.85%, with no disagreement expressed, highlighting the perceived importance of integrating watershed education into the curriculum.

Respondents also showed concern about environmental impacts, with 85.31% strongly agreeing to the statement, "I am concerned about pollution affecting the local watershed," and 8.19% agreeing. Neutral responses made up 6.50%, with no disagreement recorded.

On the statement, "I feel that the community is doing enough to protect our watersheds," the responses were predominantly negative, with 82.67% strongly disagreeing and 9.66% disagreeing. Only 2.56% strongly

agreed, suggesting dissatisfaction with current community efforts.

For "I regularly seek out information on watershed conservation practices," 92.99% of respondents (strongly disagree: 82.67%, disagree: 9.66%) indicated no proactive effort in seeking information, emphasizing the need for accessible educational resources.

Lastly, for the statement, "I believe that urban development poses a significant risk to the local watershed," 73.45% strongly agreed, 25.71% agreed, and only 0.85% were neutral, reinforcing concerns about urbanization's environmental impacts.

The analysis of the guided questions reveals strong support for watershed conservation, with most respondents recognizing its importance and advocating for increased government investment and education efforts. A significant majority expressed concern about pollution and the risks posed by urban development to local watersheds. However, the data also highlights critical gaps in awareness and participation, as most respondents felt uninformed about local watershed efforts and showed minimal involvement in conservation initiatives. This indicates a need for targeted educational campaigns, improved communication, and accessible resources to encourage active community engagement and support effective conservation practices.

Qualitative Research Findings

This section aimed to gather insights from experts and key informants on their understanding of watershed functions, the state of conservation efforts, and methods for assessing watershed health. Watersheds were recognized as vital systems that sustained ecosystems, supported biodiversity, and provided essential resources such as water for human and environmental needs. The questions in this section focused on identifying the key functions of watersheds, understanding expert perspectives on the effectiveness and challenges of conservation efforts in their regions, and exploring the indicators they used to evaluate watershed health, such as water quality, vegetation cover, and biodiversity. The information collected provided a foundation for identifying gaps, prioritizing conservation needs, and developing targeted interventions to improve watershed management.

General Understanding about Watersheds.

The question "What are the most critical functions of a watershed?" was designed to capture key informants' understanding of the roles that watersheds play in ecological and socio-economic systems. One of the participants answered.

> *"Ang pinaka functions talaga ng watershed sa atin, ay ang magbigay o supply ng tubig na pangangailanagan natin sa araw - araw, sabi nga di bale na walang pagkain pero kung may available na tubig kaya natin magsurvive ng ilang araw".*
>
> *[The primary function of a watershed for us is to provide or supply the water we need every day. As they say, it's okay to go without food, but if water is available, we can survive for several days.]*

Moreover, watersheds contribute significantly to climate regulation by acting as natural buffers, absorbing rainfall, and mitigating the effects of extreme weather events such as floods and droughts. They also support carbon sequestration through vegetation and forests within the watershed, helping to combat climate change. Watersheds are essential for socio-economic activities, providing water for drinking, agriculture, hydropower, and industrial use. Beyond their ecological and economic importance, watersheds also hold cultural and recreational value, offering spaces for tourism, spiritual practices, and community engagement. Their multifaceted role underscores the necessity of their protection and sustainable management for current and future generations.

For the next question, how would you describe the current state of watershed conservation in your municipality? Most of the participants answer the same concept of;

> *"May mga tree planting naman na sinasagawa kada taon na pinangungunahan ng LGU sa mga area na sakop ng watershed, ngunit makikita mo*

sa area na marami pa din ang nagkakaingin, nag uuling at namumutol ng kahoy, kaya patuloy pa din ang pagkasira ng kagubatan".

[There is tree planting activities conducted every year led by the LGU (Local Government Unit) in areas within the watershed, but you can still see that many engage in slash-and-burn farming, charcoal-making, and logging. As a result, the destruction of the forest continues.]

In line with this, the local government has enforced forest protection laws and implemented national forest management programs, contributing to a reversal of deforestation trends between 2010 and 2014. These efforts have enhanced carbon sequestration and improved watershed health (Waves Partnership, 2017)

Assessing the health of a watershed is critical for ensuring the sustainability of its ecological functions and the well-being of communities that rely on it. Key indicators such as water quality, vegetation cover, soil health, and biodiversity offer valuable insights into the physical and biological state of the watershed (EPA, 2021). Hydrological conditions, land use patterns, and community practices also play significant roles in determining the watershed's resilience to environmental challenges, including climate change and human activities (MEA, 2005). By monitoring these indicators, stakeholders can identify areas of concern, evaluate the impacts of land use, and develop targeted interventions to restore and conserve watershed ecosystems. This comprehensive approach ensures that watersheds remain functional and sustainable for future generations.

Next question, what are the key indicators you use to assess the health of a watershed? One of the participants answered directly.

"Maraming key indicators ang dapat tingnan, una ay ang ating forest cover makapal paba? Next, marami pa bang flora and fauna na makikita sa area, pangatlo may soil erosion ba palagi or landslide? Maraming mga icoconsider para malaman natin kung kumusta na ang watershed health ilan lang yan sa mga nabanggait ko"

[There are many key indicators to look at. First, is our forest cover still dense? Next, are there still many flora and fauna in the area? Third, is there frequent soil erosion or landslides? There are many factors to consider determining the health of a watershed, and those are just some that I mentioned.]

In addition, water quality parameters, such as dissolved oxygen levels, pollutant concentrations, and nutrient loads, are critical for assessing the health of aquatic ecosystems, with agricultural runoff and industrial discharges often linked to elevated levels of pollutants (Springer, 2024). Land use patterns, including the distribution of agricultural lands, urban areas, and natural habitats, significantly affect watershed health, with changes such as urbanization and cropland expansion associated with increased pollution and habitat loss (Springer, 2024).

Threats to Watershed. Another set of questions was posed to the key informants, focusing on their expertise in watershed conservation. One question specifically asked about the most pressing threats to watersheds in the area. Respondents were encouraged to identify and elaborate on the factors they believed posed significant risks to the health and sustainability of local watersheds.

Here is the statement most of them answered.

"Ang pinaka threat sa watershed area natin ay ang patuloy na pag mimina, pagkakaingin, pag-uuling, pagconvert ng mga area into palm plantation, pagkukuha ng buhangin at graba sa ilog at hindi tamang pagsasaka."

[The biggest threats to our watershed area are the continued mining, slash- and-burn farming, charcoal-making, conver-

sion of areas into palm plantations, extraction of sand and gravel from rivers, and improper farming practices.]

Additionally, urbanization and infrastructure development exacerbate these issues by altering natural water flow patterns and increasing impervious surfaces, leading to higher runoff and reduced groundwater recharge. The combined effects of these activities not only diminish the ecological functions of watersheds but also heighten the vulnerability of local communities to natural disasters such as floods and landslides.

Climate change significantly impacts watersheds by altering rainfall patterns, increasing extreme weather events, and disrupting the hydrological cycle. These changes lead to reduced water availability, intensified soil erosion, and degraded water quality, threatening both ecosystems and the communities relying on them Another question was asked, how has climate change impacted watershed health in your experience?

One of the responses was.

"Nakaranas tayo ng matinding baha sa ating bayan, na lumalim hanggang bubong ng mga kabahayan nitong mga nakalipas na taon, maraming naapektuhan sa nasabing pangyayari, naranasan din natin ang mahabang tag- init na halos ikinamatay ng maraming halaman at hayop. Nagpapatunay lang na nararanasan natin ang climate change, naalala ko pa ng tag-init halos natuyo ang ating mga ilog, mahinang mahina na rin ang tulo ng tubig sa gripo, kaya dapat talaga alagaan natin ang ating watershed area."

[We experienced severe flooding in our town, with water rising as high as the rooftops of houses in recent years, affecting many people. We also went through a prolonged dry season that nearly caused the death of many plants and animals. This clearly proves that we are experiencing climate change. I even remember during the dry season, our rivers almost dried up, and the flow of water from the taps became very weak. That's why we really need to take care of our watershed areas.]

These answers reflect a broad range of impacts that highlight the complex relationship between climate change and watershed sustainability.

Watershed conservation is essential for maintaining ecological balance, ensuring water availability, and supporting biodiversity. To understand effective approaches, the researcher asked key informants, "What conservation strategies or practices do you think are most effective for protecting watersheds?" This question aimed to gather expert insights on the most impactful methods to safeguard these vital ecosystems. Most of the responses are.

"Paigtingin ang mga batas na nagpoprotekta sa ating kalikasan, magtanim ng mga puno na hindi invasive sa atin, eeducate din dapat ang mamayan na maging responsible sa pagsasaka at palawakin ang community engagement sa mga programa ng gobyerno na may kinalaman sa conservation and management"

[Strengthen the laws that protect our environment, plant trees that are not invasive to our area, educate the citizens to be responsible in farming, and expand community engagement in government programs related to conservation and management.]

Watershed conservation strategies and best practices have been widely studied and implemented in the Philippines, focusing on reforestation, community engagement, and integrated management approaches.

One notable example is the restoration of the Ipo Watershed, which highlights the critical connection between forests and water resources. The project employs reforestation efforts and active collaboration with local communities to improve water quality and ensure sufficient water supply for Metro Manila (WWF Philippines, n.d.).

The Tigum-Aganan Watershed presents another successful case, demonstrating how partnerships between non-government organizations and local governments can promote sustainable watershed management. These collaborations effectively address challenges such as

deforestation, water pollution, and erosion (Springer, 2021).

Moreover, the National Greening Program (NGP) launched by the Philippine government in 2011 aims to reforest degraded forestlands and improve watershed health. This program emphasizes community-based forestry, empowering local communities to participate inconservation initiatives while restoring critical watershed functions (ACIAR, 2019).

Policy and Governance. Strong governance frameworks, including laws, regulations, and community engagement, help address threats such as deforestation, pollution, and unsustainable land use. Integrating policies that promote reforestation, sustainable agriculture, and strict enforcement of environmental laws ensures the long-term health and functionality of watersheds. Collaborative efforts between governments, NGOs, and communities are essential to enhance watershed management and safeguard these critical ecosystems for future generations. For this section question one theme answers have been withdrawn from the key informants.

> *"Maganda ang mga policy from national down to local when it comes to watershed protection, ngunit hindi eto nabibigyan ng mataas na importansya dahil sa kalulangan sa mga pondo at tao na mangangalaga nito. Ang tendency hindi gaanung nabibigyang pansin ang problema sa watershed area na dapat sana ay isa sa maging priority ng ating munisipyo sapagkat nag iisa lng ito at nakakabahala ang mataas na porsyento kada taon nauubus ang ating kagubatan. Meron tayo Pulot Watershed Management Plan for 2012-2037 gawa ng USAID napakaganda ng mission at vision ngunit hindi lahat naipatupad dahil kulang sa pondo."*
>
> *[The policies from national to local levels regarding watershed protection are good, but they are not given high importance due to a lack of funding and personnel to manage them. As a result, the issues in watershed areas are not given enough attention, even though they should be a priority for our municipality, as we only have one watershed. It is alarming that a high percentage of our forests are being lost each year. We have the Pulot Watershed Management Plan for 2012-2037 created by USAID, which has an excellent mission and vision, but not all of it has been implemented due to a lack of funding]*

In conclusion, while there are comprehensive policies and plans in place for watershed protection, such as the Pulot Watershed Management Plan, their effectiveness is hindered by limited funding and manpower. This lack of resources results in insufficient attention to critical issues, such as deforestation and degradation of watershed areas, which should be prioritized given their vital role in sustaining ecosystems and communities.

To fully realize the mission and vision of these policies, it is imperative to secure adequate funding, strengthen local government initiatives, and enhance community involvement to ensure the long-term sustainability and health of watersheds.

To summarize, watersheds are essential for sustaining ecosystems, providing clean water, and supporting biodiversity, yet they face significant challenges due to deforestation, mining, land conversion, and climate change. Key informants highlighted the critical functions of watersheds, including regulating hydrological cycles, preventing soil erosion, and maintaining biodiversity, but described their current state as inadequate due to insufficient conservation efforts. Indicators such as forest cover, water quality, and soil stability were emphasized as vital for monitoring watershed health. Effective conservation strategies, such as reforestation, riparian buffer zones, and sustainable agricultural practices, were noted, with a strong emphasis on community engagement and education to foster local ownership of conservation efforts. While national and local policies on watershed protection are well- structured, their implementation is hindered by funding and enforcement challenges. Respondents recommended prioritizing funding, improving interagency collaboration, and strengthening partnerships among governments, NGOs, and

communities to ensure more effective watershed management.

In conclusion, these insights underscore the need for a multi-stakeholder approach that integrates robust policy enforcement, scientific knowledge, and community-driven actions to protect and restore watershed ecosystems for future generation.

Conclusion

The findings of this study highlight the critical importance of sustainable water resource management and watershed conservation in Sofronio Española, Palawan. The Pulot Watershed, a vital resource sustaining the municipality's water supply and ecological balance, faces numerous challenges driven by population growth, urbanization, and environmental degradation. From 2011 to 2023, significant increases in water demand and consumption were recorded, underscoring the pressing need to expand and enhance water supply infrastructure. However, the rapid rise in water usage, coupled with the projected growth of consumers by 2050, threatens to outpace the current system's capacity, creating an urgent need for alternative water sources, efficient resource management, and innovative conservation technologies.

The environmental state of the Pulot Watershed underscores its vulnerability. With a net loss of 202 hectares of forest cover between 2005 and 2020 and the complete conversion of closed forests into open forests, the watershed's ability to regulate hydrological processes has been severely compromised. Deforestation, driven by logging, charcoal-making, slash-and- burn farming, and mining, exacerbates soil erosion, sedimentation, and water quality degradation. Urbanization and improper land- use practices have further stressed the watershed, altered natural water flow patterns and reduced groundwater recharge.

Climate change compounds these challenges, intensifying extreme weather events that disrupt the hydrological cycle and threaten both ecosystems and community livelihoods. Despite these challenges, community awareness and participation in watershed conservation remain limited, with significant gaps in understanding and engagement. While respondents overwhelmingly recognize the importance of watershed protection, actual participation in conservation initiatives is minimal. However, there is strong support for measures such as reforestation, stricter environmental regulations, and sustainable agricultural practices. Respondents also advocate for enhanced educational campaigns and integrating watershed conservation into school curricula to address the lack of awareness and foster a sense of environmental responsibility.

Policy and governance frameworks, including the Pulot Watershed Management Plan (2012–2037), provide a solid foundation for conservation efforts. However, the effectiveness of these policies is hindered by insufficient funding, inadequate manpower, and weak enforcement. Addressing these limitations requires a multi-stakeholder approach that prioritizes funding, strengthens local governance, and fosters collaboration among government agencies, NGOs, and local communities. Examples of successful watershed restoration initiatives in other regions demonstrate the value of community-driven, integrated management approaches in achieving long-term sustainability.

In conclusion, the sustainability of Sofronio Española's water resources and the health of the Pulot Watershed depend on coordinated, urgent actions to address environmental, social, and governance challenges. A holistic strategy that combines scientific knowledge, community engagement, and robust policy implementation is essential to protect the watershed, ensure water security, and enhance resilience to climate change. By prioritizing conservation and fostering partnerships, the municipality can safeguard its natural resources for future generations while promoting sustainable development and ecological balance.

Acknowledgement

The researcher expresses her deepest gratitude and utmost praise to Almighty God, whose boundless blessings, guidance, and wisdom have strengthened her throughout this academic journey. She acknowledges that,

without His grace, this endeavour would not have been possible.

She extends her heartfelt thanks to Palawan State University- Graduate School headed by an excellent Dean Dr. Ma. Teresita F. Jardinico, particularly its esteemed faculty and staff, for providing the foundation and support essential for her growth as a researcher.

To her adviser, Dr. Rodolfo O Abalos Jr., for his unwavering trust in her abilities, which motivated her to pursue this thesis with confidence. His belief in her capacity has been truly inspiring.

To Dr. Maria Rosario Aynon Arciaga-Gonzales, Chairperson of the Graduate School - Science, for always keeping the lines of communication open, answering her endless queries, and encouraging her to complete this thesis.

To Sir Hermenegildo P. Dela Peña, a panelist, for sharing his expertise and offering valuable technical assistance that greatly improved her work.

A special mention goes to Ms. Maricel V. Elorde for her patience and dedication in meticulously reviewing the paper; her time and effort have meant the world to her.

She extends her heartfelt appreciation to Ma'am Judith Misajon, her English critic, whose meticulous review and feedback have been instrumental in refining this thesis.

Her profound thanks go to Dr. Ronald Edilberto A. Ona, whose encouragement to align her master's degree with her specialization inspired her to stay true to her academic goals. She is also grateful to Dr. Michael D. Pido for his humility, genuine support, and instrumental guidance throughout this challenging journey, as well as to Dr. John Patrick A Regoniel, whose significant guidance in statistics was invaluable to the success of her research.

A special acknowledgment is extended to Dr. Arnica D. Mortillero an expert researcher from PCSD, whose tireless support, willingness to address her countless questions, and expertise in environmental research have been a cornerstone of her thesis. She feels truly fortunate to have benefited from such guidance and mentoring. The researcher extends heartfelt gratitude to her special friend, Rutchell C. Gauranoc, whose unwavering support and encouragement have been a constant source of strength throughout this journey. The researcher also sincerely appreciates the local government of Sofronio Española for their vital assistance and cooperation in facilitating this study. Theirsupport in providing resources and logistical coordination was invaluable, as was the active participation and honest contributions of the respondents from each barangay, whose insights were crucial to the success of this research.Lastly, the researcher deeply thanks her family for their unwavering support and inspiration, especially her husband, Rigor V. Jabagat, their children, Bobshyne and Lincoln, her father, Ruby, and her late mother, Patricia, whose enduring guidance and spiritual presence continue to inspire her.

Recommendation

The research emphasizes the importance of strengthening policy and governance for effective watershed management in the Pulot Watershed. Key actions include allocating dedicated funding, hiring trained personnel, and enforcing environmental laws. Additionally, integrating watershed conservation into local development plans and fostering interagency collaboration are crucial for long-term sustainability Finally, continuous monitoring, evaluation, and improvement are necessary for ensuring the effectiveness of the management strategies. Developing Key Performance Indicators (KPIs), conducting periodic audits, and investing in research and development will ensure progress. Additionally, procuring advanced monitoring equipment and training personnel in their use will improve data collection and decision-making for better management of the Pulot Watershed.

To address the challenges identified in this study and ensure sustainability of water resources and the health of the Pulot Watershed, a comprehensive and multifaceted approach is essential.

These recommendations are also aligned with Sustainable Development Goals (SDG) Number Six (6), which emphasize ensuring the availability and sustainable management of water and sanitation for all the following strategies.

Goal	Action	Key Activities	Stakeholders
Strengthening Policy and Governance	Allocate Dedicated Funding	Allocate budget for the Pulot Watershed Management Plan	Local Government of Sofronio Española Provincial Government of Palawan Palawan Council and Sustainable Development Office NGOs Environmental Agencies, Law Enforcement
	Hire and Train Personnel	Recruit and train watershed management staff	
	Strengthen Policy Enforcement	Enforce environmental laws	
	Integrate Watershed Conservation in Local Development Plans	Align plans with environmental goals	
	Encourage Interagency Coordination	Facilitate collaboration	
	Conduct Educational Campaigns	Raise public awareness	Palawan State University Faculty and Staff and
	Integrate	Include watershed topics in curricula	
Enhancing Community Awareness and Engagement	Watershed Education into Schools	Crafting, fliers, infographics, modules and other materials	its Extension and Services Office Department of Education Schools and Community
	Foster Community Participation	Encourage community-led initiatives	
	Support Livelihood Alternatives	Train in sustainable practices	
Implementing Conservation Strategies	Reforestation and Restoration	Plant native species	Municipal and Environment and Natural Resources Office (MENRO- Española) Communities Farmers Agricultural Agencies Urban Planners, LGUs, Industries Agricultural and Environmental Groups
	Sustainable Agriculture Practices	Promote eco-friendly farming techniques	
	Control Urban Expansion	Enforce zoning regulations	
	Enhance Water Infrastructure	Upgrade systems	
	Address Runoff	Erosion control measures	

Goal	Action	Key Activities	Stakeholders
	and Sedimentation		
Building Climate Resilience	Develop Climate-Resilient Strategies	Enhance forest cover, diversify water sources	Climate Experts LGUs Research Institutions LGUs Environmental NGOs, Communities
	Monitor Climate and Hydrological Changes	Set up monitoring systems	
	Promote Ecosystem-Based Approaches	Use nature-based solutions	
Fostering Partnerships and Collaboration	Encourage Public-Private Partnerships	Involve private sector	Businesses, Local Authorities NGOs Local Organizations Neighbouring Municipalities
	Strengthen NGO and Community Networks	Collaborate on education and advocacy	
	Promote Regional Collaboration	Develop unified watershed management	
Monitoring, Evaluation, and Continuous Improvement	Develop Key Performance Indicators (KPIs)	Measure watershed health	LGUs Researchers Independent Auditors Research Institutions NGOs
	Conduct Periodic Audits	Evaluate program effectiveness	
	Invest in Research and Development	Support innovative techniques	
Implementing Conservation Strategies	Procure Equipment for Effective Monitoring	Purchase flow meters, water quality sensors, drones, sediment samplers, and weather stations. Train personnel in their use.	LGUs Sofronio Espanola Waterworks System Research Institutions NGOs

By implementing these recommendations, the municipality of Sofronio Española can address the pressing challenges identified in this study, safeguard its water resources, and ensure the sustainability of the Pulot Watershed. Coordinated efforts among stakeholders, robust governance, and active community involvement are critical to achieving long-term ecological and socio- economic resilience In conclusion, the recommendations provided offer a comprehensive approach to addressing the challenges faced by the Pulot Watershed and the water supply system of Sofronio Española. By strengthening policy and governance, enhancing community awareness and engagement, implementing targeted conservation

strategies, building climate resilience, and fostering collaboration among stakeholders, the municipality can protect its vital water resources. These actions are not only essential for ensuring sustainable water supply and environmental protection but also for promoting long-term socio-economic development.

The success of these initiatives relies on the commitment of local governments, communities, and private entities, all working together to create a resilient future. Continuous monitoring, evaluation, and innovation are key to ensuring the effectiveness of these strategies.

If successfully implemented, Sofronio Española can serve as a model for integrated watershed management, demonstrating the potential of collective action in addressing environmental and resource challenges.

The study contributes significantly to improving watershed management by identifying the critical role of policy strengthening and governance frameworks. The recommendation for dedicated funding for watershed management and enforcement of environmental laws addresses the gaps in local governance.

The action plan emphasizes the importance of community engagement, which is crucial for ensuring the sustainability of conservation efforts. Additionally, the promotion of sustainable practices, such as reforestation, sustainable agriculture, and urban zoning, will help restore the health of the watershed, enhancing its ability to meet water demands.

To improve watershed management, key actions include securing dedicated funding for the Pulot Watershed Management Plan, strengthening the enforcement of environmental laws by local authorities and agencies, involving communities in sustainable practices while offering livelihood alternatives, promoting environmentally friendly farming and reforestation initiatives to safeguard soil and water quality, and upgrading water infrastructure to improve distribution efficiency and minimize losses.

Future research should investigate the effects of climate change on water resources in the Pulot Watershed, particularly regarding shifts in rainfall patterns, droughts, and the increasing frequency of extreme weather events. Studies could also explore innovative water management technologies, like water reuse systems and drought-resistant crops, to mitigate climate change impacts. Additionally, research should focus on ecosystem-based adaptation strategies, such as wetland restoration and forest conservation, to enhance the watershed's resilience.

Further studies on the socio-economic impacts of water shortages and conservation measures will provide valuable insights to guide policy decisions and ensure the needs of local communities are effectively met.

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