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Status of Utilization of Hydraulic Ram Pump

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ABSTRACT: The study assessed the current status of hydraulic ram pump utilization in the Philippines. This developed a georeferenced map showing the location of established hydraulic ram pump installations and described the spatial patterns of ram pump installations. A systematic review and meta-analysis approach guided by PRISMA 2020 standards was employed to collect and synthesize data from peer-reviewed publications, institutional reports, and online sources. Web-based data collection and geocoding techniques were used to determine installation locations, which were then analysed through geospatial and artificial intelligence–assisted interpretation. A total of ninety-three (93) hydraulic ram pump installations were identified nationwide. Results revealed that adoption is unevenly distributed and concentrated primarily in regions with favourable topography, watershed availability, and rural water demand. Regions with mountainous and upland characteristics exhibited higher utilization, while highly urbanized areas and regions with institutional and infrastructural constraints showed minimal or no installations.

KEYWORDS: Ram pump, hydraulic, georeferenced map, geospatial, geospatial

I. INTRODUCTION

Access to clean and reliable water remains a critical challenge in many rural and remote areas, especially where electricity and fuel sources are limited or unavailable. Traditional water pumping systems often rely on electric or fuel-powered mechanisms, making them unsustainable and costly in off-grid communities. In this context, the hydraulic ram pump presents a compelling alternative due to its ability to pump water without external power sources, relying solely on the kinetic energy of flowing water.

Around 7.5 million out of 94 million Filipinos have no access to water supply facilities, especially for residents living in the highlands with small-scale agricultural farming [1]. Hence, providing water pumping technology that does not require electricity or diesel fuel as the alternative water pumping technology called hydraulic ram pump can be helpful in their living conditions. Following the increasing awareness of the adverse impact of global warming and the needs of sustainable technology, interest in hydraulic ram pump for water supply purpose has revived [2]. The device is suited to be connected for it can supply water at higher elevation of the inlet water and has a higher possibility to operate as a pumping device in remote areas with scarcity of water supply coverage. Hydraulic ram pump is a self-operating water pumping equipment without external energy input, which converts low-head potential energy of a large volume of water into high-head potential energy of a small portion making it to be used [3]. The hydraulic ram pump which was introduced as a sustainable low-cost alternative solution to the more conventional pressure reducing valves (PRVs) approach is a cyclic water pump powered by hydropower, generally used to pump drinking and irrigation water in mountainous and rural areas having short of power [4] with the main concept to exploit the momentum of a driving stream of water undergoing a head drop to pump a small portion of the stream to a head considerably greater than that of the supply. The device if well-designed is very durable that can operate for long period of time since it includes only two check valves as moving parts, a drive valve, and a waste valve, both of which operate automatically from the fluid dynamic actions of the pumping cycle [5]. It is also an environmentally friendly equipment due to no consumption of fossil fuels [6].

In the 19th and 20th centuries, the device was used worldwide that provided fresh water for domestic water supply and irrigation for farmlands, however was became outdated and obsolete with the introduction of water distribution networks and electrical supplies. Recently, however, enthusiasm for low-cost, low-maintenance, environmentally friendly devices using a renewable energy resource has revived interest in the 200 years old technology and its use for water supply in developing countries [7]

In the Philippine, there is no accessible listing that provides a consolidated and publicly accessible inventory or geospatial map of all documented ram pump located nationwide. Hence, this study was conducted.

II. OBJECTIVE

The main objective of this study is to assess the current status of utilization. The specific objectives are: to assess the status of utilization in the Philippines; to develop and present a georeferenced map showing the location of established hydraulic ram pump installations within the study area; and to describe the spatial patterns of ram pump installations.

III. METHODOLOGY

This adopted a systematic review and meta-analysis approach, guided by PRISMA 2020 standards, to comprehensively assess the utilization of hydraulic ram pumps in the Philippines. The PRISMA 2020 statement includes new reporting guidance that reflects advances in methods to identify, select, appraise, and synthesize studies [8]. The related searches were drawn from peer-reviewed databases, and targeted web and electronic searches. Eligible articles and studies that were included are field implementations reporting on utilization, performance, functionality, cost-effectiveness, or community satisfaction. Quantitative data were synthesized through random-effects meta-analysis that where feasible, while qualitative findings undergone thematic synthesis, ensuring a robust, transparent, and reproducible evaluation. This is exemplified in step-by-step instructions depicting various stages of the process [9].

Data collection methods differ depending on the subject or topic of study, the type of data sought, and the user’s aims [10]. Depending on the goals and conditions, the method’s application methodology is changing without jeopardizing data integrity, correctness, or reliability [11]. Data were accessed from a wide variety of databases, whether printed or virtual data, quickly from online sources using web scraping which is now become an important tool in the field of data collection in the operation of online sources [12]. This study used web scrapping in order to know the exact location of the hydraulic ram pump existence in the Philippines through on-line searches. Although web scraping is a promising tool for geographic data acquisition [13], it is widely utilized for a variety of purposes, including comparing prices online, observing changes in weather data, website change detection, research, integrating data from multiple sources, extracting offers and discounts, scraping job postings information from job portals, brand monitoring, and market analysis [14]. Web scraping is the process of autonomous data mining or gathering information from the Internet and other common databases. On this study, the copy-pasting method was simply applied by accessing the page using browser, then manually copy and paste it onto other media. Nevertheless, even the method is pretty easy and straightforward if the website employs a barrier program, is difficult to use [11] requiring a human selection process. Most data on this study were accessed through web scrapping [15], [16], [17], [18], [19], [20] through on-line sources.

The georeferenced map was produced through Geocoding. Geocoding is the process of assigning geographic coordinates on the Earth's surface to associated georeferenced textual information, such as postal addresses and place names [21], [22], [23]. On this process street addresses, name of places, postal codes and landmarks were able to be converted into geographic coordinates reflecting latitude and departure that later are placed into a map using artificial intelligence. The process of geocoding forms a basic fundamental component of spatial analysis in a wide variety of research disciplines and application domains such as in health [24], [25], [26] and crime analysis [27], [28]; political science [29]; computer science [30], [31]. It was also used in historical researches such as in automatic georeferencing of historical maps [32]. It is the process of transforming indirect spatial information into direct locations which can be placed on a map, thus allowing for spatial analysis and cross-referencing [33]. It was often used in epidemiologic studies to map residences with geographic information systems (GIS) [34]. These acts of turning descriptive locational data such as a postal address or a named place into an absolute geographic reference has become a critical piece of the scientific workflow [21].

AI-based geospatial interpretation was used to read the generated georeferenced map. An analysis by georeferenced map using image and spatial recognition is a rapidly advancing field, merging Geographic Information Systems (GIS) with Artificial Intelligence (AI) to automate the analysis of satellite, aerial, and street-level imagery. This process works in simple terms such as the following: a) Data Input or Georeferenced Data Processing by which the map with coordinates such as latitude and longitude is uploaded or provided to the AI system; b) Image or Spatial Recognition wherein AI analyzes the map using computer vision or machine learning to detect features like roads, buildings, rivers, land use, or elevation patterns; c) Coordinate Interpretation wherein the AI reads the geographic reference information such as coordinate system, projection, and scale to understand real-world positions; d) Spatial Analysis wherein the system evaluates relationships between features like the distance, direction, proximity, and patterns; and e) Natural Language Explanation wherein the technical spatial analysis were converted into human readable explanations. Geospatial Artificial Intelligence or GeoAI, as the integration of geospatial studies and AI, has become one of the fastest-developing research directions in spatial data science and geography [35]. Experts have extensively explored the advantages and applications of modern AI algorithms across various domains connecting that integrating AI techniques into geomatics has given rise to GeoAI, a novel approach to uncovering geographic information [36].

IV. RESULT AND DISCUSSION

The status of utilization of the hydraulic ram pump in the Philippines, the georeferenced map showing their location and the spatial patterns of ram pump installations were described as follow.

A. *Status of utilization*

The analysed data shows that utilization of hydraulic ram pump is widely distributed across the country however the technology is currently underutilized at the national scale. Compared to the country’s thousands of rural and upland communities that face water access challenges, the number remains relatively small. The hydraulic ram pumps have not yet been widely implemented as a typical rural water supply solution as shown in Table 1.

Table 1. Utilization of the hydraulic ram pump by region

Region	**Number of Hydraulic Ram Pump**
1	1
2	2
3	9
4A	7
4B	7
5	6
6	12
Negros Island Region	6
7	4
8	7
9	3
10	6
11	4
12	11
CAR	5
CARAGA	3
BARMM	0
NCR	0
Total	93

Table 1 revels that Region 6 has the highest number with twelve (12) installed hydraulic ram pump. This is seconded by the Cordillera Administrative Region (CAR) with eleven (11) and Region 3 with nine (9) installed devices. Strongest adoption of the technology is strongest in Region VI for having the highest number of hydraulic ram pump installations. The presence of numerous upland and rural communities, suitable topographic conditions, and available flowing water sources is attributed to the situation, which are essential for effective ram pump operation. The area had been the focus of concentration of installations for rural water supply interventions utilizing gravity-driven and energy-independent technologies.

The Cordillera Administrative Region (CAR**)** for having the second highest number of installed hydraulic ram pumps may be attributed to the area's mountainous terrain and significant elevation differences that provided highly favorable conditions for ram pump applications. This also reflects the technical suitability of the technology as well as the influence of development programs and institutional support aimed at improving water access in geographically isolated and disadvantaged areas.

Despite of being more economically developed and partially urbanized, Region 3 still obtains the area with third highest number of hydraulic ram pump which could be attributed to its upland and agricultural areas where centralized water systems are limited. The presence of ram pumps in the area suggests a selective and localized utilization, particularly in communities where conventional pumping systems are either costly or impractical.

As a whole, the distribution pattern in the country indicates that hydraulic ram pump utilization is concentrated in regions with favorable terrain, rural water demand, and targeted development initiatives, rather than evenly distributed nationwide.

In the case of the National Capital Region (NCR), the area is highly urbanized and densely populated, with well-established centralized water supply **sys**tems operated by major water utilities. Hydraulic ram pumps require natural flowing water sources and sufficient elevation differences, conditions that are largely absent in NCR due to extensive land development, river channelization, and limited upland terrain. As a result, ram pump technology is technically unsuitable and unnecessary in an urban context where electric pumping systems and piped water networks are readily available.

In case of the Bangsamoro Autonomous Region of Muslim Mindanao (BARMM), the absence of ram pump installations is less related to urbanization and more to institutional, technical, and development constraints. Although the area is rural and upland which could be considered physically suitable, the challenges are limited infrastructure investment, lower technical capacity, security concerns, and reduced exposure to alternative water technologies. Additionally, water supply projects in the region were often prioritized as short-term or conventional rather than site-specific or gravity-based systems like hydraulic ram pumps.

Lack of ram pump installations in the two areas does not necessarily indicate unsuitability of the technology nationwide. It highlighted how contextual factors such as urban infrastructure dominance in NCR and developmental and institutional limitations in BARMM are strongly influencing the technology adoption. The condition underscores the importance of site-specific planning and targeted policy support when promoting sustainable water technologies in the Philippines.

Figure 1. The Georeferenced Map Showing Hydraulic Ram Pump Locations in the Philippines

Reflected in the map are the distribution of hydraulic ram pump installations in the Philippines showing a clear spatial pattern that were strongly influenced by terrain, watershed characteristics, and elevation. It was demonstrated in the map that hydraulic ram pumps in the Philippines are strategically located in terrain with sufficient slope, closely tied to upland watershed systems and are designed to serve remote, elevated communities without electricity.

B. *Spatial patterns of ram pump installations*

National Spatial Distribution: The ram pumps are scattered across Luzon, Visayas, and Mindanao, that are clustering in mountainous and upland provinces; interior barangays instead in coastal plains; and on areas adjacent to rivers, creeks, and spring-fed streams. This confirms that hydraulic ramp pump systems are primarily deployed in the following areas: rural, off-grid, and gravity-fed water supply.

Relation to Terrain: A ram pump can work only when a continuous supply of water is provided from a source at appropriate head [37]. The mapped points are mostly found in foothills and rolling terrain such as in Bataan, Quezon and Camarines Sur; mountainous interiors like those located in Nueva Vizcaya, Benguet, Bukidnon and Negros Oriental; at volcanic and karst landscapes where springs and steep stream gradients are common while for flat lowland areas like in the plains of Central Luzon plains show very few or no installations indicating terrain unsuitability.

Relation to Watersheds: The map shows that Most ram pump sites are located within upper to mid-watershed zones, along tributaries rather than major rivers and near perennial streams fed by forested catchments, the areas that ensures continuous water flow year-round, cleaner water sources and adequate pressure head from upstream elevation. It can be seen that many installations support small upland communities and agricultural areas downstream of forested watersheds. The hydraulic ram pump can be can be placed near the river so that water can be supplied to agricultural activity and water pool area [38]. It is a technology that utilized the potential energy of water received from the elevated source [39] that creates a water hammer effect that pushing a certain amount of water to higher elevations in a periodic operating cycle [40].

Relation to Elevation: From the spatial pattern: The ram pumps are typically installed at low-to-mid elevations particularly from 50–500 meters above sea level near streams. The water is then lifted to higher elevations often ten (10) to fifty (50) meters above the pump to supply hilltop barangays, upland farms and gravity-fed storage tanks. Effective use of natural elevation differences is clustered in Cordillera, Bicol, Negros, and Mindanao uplands.

Regional Observations.: In the island of Luzon, concentrations ire observed in Cordillera, Sierra Madre, Bataan, and Bicol areas reflecting rugged terrain and strong watershed systems. In the island of Visayas, most installations are seen in Negros, Panay, Leyte, and Samar that are corresponding to interior mountain belts and river headwaters. In the island of Mindanao, the presence of the hydraulic ram pump is common in Bukidnon, Davao, Sultan Kudarat, and Zamboanga regions that are aligning with extensive upland watershed. The spatial distribution highlighted the hydraulic ram pump's role as a sustainable, low-cost water supply technology well-suited to the country's mountainous and watershed-rich geography.

V. CONCLUSION

A total of ninety-three (93) hydraulic ram pump installations were identified in the Philippines with higher concentrations observed in regions characterized by mountainous terrain, abundant watershed resources, and communities located at higher elevations.

The distribution pattern demonstrates that the implementation of the hydraulic ram pump is strongly influenced by physical suitability factors, particularly terrain slope, elevation differences, and the presence of perennial water sources. Regions such as Western Visayas, the Cordillera highlands, and selected upland provinces in Luzon and Mindanao showed greater implementation due to favorable environmental conditions and targeted development interventions. On the other hand, the absence or low number of installations in highly urbanized areas and regions with institutional or infrastructural limitations indicates that the adoption of the technology is not solely dependent on physical suitability but also on governance, technical capacity, funding availability, and program awareness.

The hydraulic ram pumps are typically installed within upper to mid-watershed zones, near tributaries and spring-fed streams, and are primarily intended to serve off-grid upland communities where conventional water supply systems are impractical or costly. The technology's ability to operate without electricity, combined with its durability and low maintenance requirements, reinforces its relevance as a sustainable rural water solution.

The hydraulic ram pump technology remains an underutilized yet highly appropriate water supply option in the Philippines, however is underrepresented in recent engineering discourse [41]. Expanding of its implementation will require stronger institutional support, increased technical promotion, community awareness programs, and integration into rural water development policies. With proper planning and targeted implementation, hydraulic ram pumps have significant potential to contribute to improved water accessibility, sustainable resource management, and climate-resilient rural development in geographically isolated and disadvantaged areas.

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