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Empowering Smart Health Cities Through Innovative Water Management Strategies

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ABSTRACT

The Healthy City concept aims to improve the physical and social environment in order to expand community resources and strengthen daily life functions, one of which is through healthy, clean water management. The aim of this research is efficient clean water management, with a special focus on Pagak District, Malang Regency, Indonesia, which often faces the challenge of drought. Water Poverty Index (WPI) analysis and Social Network Analysis (SNA) are used to achieve this goal. WPI is a comprehensive tool that considers five main components: availability of water resources, access to clean water, adequate water management capacity, efficient water use, and the impact of water management on the environment. Next, SNA analysis is carried out as a systematic approach to understanding social capital in a community, thereby enabling a deeper understanding of social dynamics and available resources. The research results show that in Pagak District, Tlogorejo Village has the lowest WPI value of 44.51, which is categorized as critical. Apart from that, Tlogorejo Village also has the lowest SNA score with a participation rate of 1.39 and a relationship density of 35.3%. Implementing the Healthy City concept recognizes the importance of overcoming the challenges of clean water management in areas experiencing water scarcity through improving the physical and social environment. Implementation of this strategy not only increases access to clean water but also strengthens social ties and overall community well-being.

1. INTRODUCTION

As an element of life, water has an important role in maintaining ecosystem balance and human welfare [1]. Management of clean water resources is critical to sustaining life, improving health, and ensuring sustainable economic and societal development. Water, which constitutes about 70% of the earth's surface, is essential for life and various economic sectors, including agriculture, industry, and domestic use. Rapid urbanization and industrialization have significantly degraded water quality, causing severe health problems and necessitating a shift towards more efficient and cost-effective water quality monitoring systems [1, 2]. As an element of life, water plays a crucial role in maintaining ecosystem balance and human welfare [3]. The availability of clean and safe water is not only a necessity but a necessity to ensure the survival of all forms of life. Currently, in the rapid development of cities such as Pagak District, challenges related to clean water are increasingly complex. Rapid population growth and rapid urbanization significantly impact water availability and quality. High levels of human activity and environmental changes pose serious threats to clean water resources [4-6].

Clean water acts as a source of life and a determining factor in maintaining human health and welfare. Lack of access to clean water can cause disease and harm daily life. Therefore, studying clean water is an urgency that cannot be ignored. In an urban environment that continues to develop, a deep understanding of clean water conditions is a prerequisite for ensuring the sustainability of life and community development [7-9]. In dealing with the complexity of clean water management, evaluation tools such as WPI are key in providing a holistic understanding of the water poverty level in a region. The WPI considers aspects of water availability and accessibility, use, and quality of water [10-12]. In this way, we can see a comprehensive picture of the challenges and opportunities in clean water management in Pagak District.

The importance of clean water management is not only limited to technical aspects. Institutions, in this case, play an equally important role in decision-making and implementing policies related to clean water. Effective clean water management requires a deep understanding of the institutional dynamics [13, 14]. Thus, SNA is a strategic step to understand the pattern of relationships between institutions in joint efforts to maintain and manage clean water in the Pagak District.

Malang Regency often experiences a shortage of clean water due to droughts that often occur in various sub-district areas. This drought forced many people to take water from neighboring villages about 1 (one) kilometer away. Assistance and steps from the government and community groups are very important when the dry season arrives. Pagak District is one of the sub-districts in Malang Regency, with 659 *PDAM* (Municipal Waterworks) customers and 49,724 residents living in 18,015 houses. This sub-district often experiences drought and clean water crises during the dry season. In several villages, such as Sumberkerto Village, water distribution is carried out rotating to meet daily needs. Based on these issues, this research examined the empowerment of smart health cities through innovative water management strategies in Pagak District, Malang Regency.

This research has dual objectives through a combination of WPI and SNA analysis. First, identify and analyze the level of water poverty in Pagak District. Second, investigate patterns of inter-institutional relations that can influence the effectiveness of clean water management. Thus, it is hoped that this research can provide an in-depth understanding that supports policy improvements and the implementation of concrete actions. The aim is to increase the efficiency and sustainability of clean water management in Pagak District and create a healthy and sustainable urban environment.

2. LITERATURE REVIEW

2.1 Healthy City

Healthy Cities according to the Joint Regulation of the Minister of Home Affairs and the Minister of Health Number 34 of 2005 Number: 1138/Menkes/PB/VIII/2005 concerning the implementation of Healthy Regency/Cities article 1 (3), namely a condition of the Regency/City that is clean, comfortable, safe and healthy for the population to live in, which is achieved through the implementation of several integrated arrangements and activities agreed upon by the community and local government. According to these joint regulations, every city district is obliged to guarantee public health through various efforts, including community movements to create independent health. The World Health Organization (WHO) reminds us that a city must have a shared awareness to improve the quality of life of its citizens. The concept of a healthy city is not only a safe, pleasant and green environment, but also one that creates and maintains health by addressing social and economic conditions [15, 16].

WHO has played an important role in the development of the "Health Cities" concept and its development. At its core, the Health Cities movement is about the relationship between living conditions in urban areas and health. The definition of “health” and the most appropriate means of ensuring good health in urban contexts is experiencing rapid growth fueled by very serious health problems associated with urbanization, and issues such as inadequate water supply, sanitation, waste collection, pollution control, and housing. The ongoing debate has given rise to many ideas and initiatives contributing to concepts that support the Health Cities concept. The concept of "health" in this case is based on the definition of health that was adopted at the founding of WHO in 1948 which defines health as a state of complete physical, social and psychological well-being of humans, not just the absence of disease or weakness. In 1977, WHO recommended that action on health should include a strong focus on preventing disease by providing adequate water and sanitation. In accordance with the Health Cities concept, health policy must be seen as a series of processes that raise awareness, mobilize community participation and develop the role of local government in public health to encourage health as an activity that shapes the lives of individuals, households, communities and cities [17-19].

2.2 Water Poverty Index (WPI)

Poverty is an event where individuals are unable or have difficulty meeting their needs (inability to fulfill needs), as well as minimum primary needs such as access to health, education, clean water, and sanitation [20]. One indicator of poor people is water poverty, which is the condition of not meeting the need for water for daily community needs. People are categorized as water-poor if water availability is insufficient for their basic needs [21]. Based on the 2019-2024 East Java Province Regional Poverty Reduction Plan Document, poverty in an area is influenced explicitly by employment, health, education, and primary infrastructure conditions, including road conditions, electricity, access to healthy sanitation, and clean water [22]. Infrastructure, especially related to the provision of clean water, significantly contributes to the poverty level, so the provision of basic infrastructure has an important role in reducing the poverty level [23].

2.3 Social Network Analysis (SNA)

Social bonds could be a form of social capital in the context of norms and networks that get people to act collectively. Community involvement equals stronger social ties that could make social capital work [24]. Therefore, it can be said that a community that has a good connection and social network, alongside with quality of health, education, and standard of living, potentially has advantages in the mobilization towards the development of certain areas, especially in rural areas that are underdeveloped and living below the poverty line [25, 26]. SNA is an approach used to understand and measure relationships and interaction patterns inside communities between individuals or groups in a social network [27]. This method is intended as an analytical tool for mapping social structure in a society through connectivity between members of society within membership in an institution in a framework [28].

There are various types of measurements for SNA based on the purpose and intention of research, some of which are rate of participation (RoP) and density. RoP approach aims to discover the level of participation of respondents in existing community groups. The value of the rate of participation varies depending on the presence of the community in participating within the community groups, where the more active community in participating will be known by the higher value of RoP in a particular area [29]. On the other hand, density is used to get the average substance number of activities between respondents in certain areas. Density approach is intended to acknowledge how many numbers of activities occur by any pair of respondents in each community group, where the higher value of density describes a more even dense and solid social relation among respondents in a certain area [20, 29].

The relationship between Healthy City theory, WPI, and SNA in healthy water management in Indonesia is diverse and interdependent. Healthy Cities Theory emphasizes the importance of integrating physical and social infrastructure to improve community health and well-being. The WPI is able to measure access to clean water through five components, revealing significant differences between poor and non-poor households, with non-poor households having better access to clean water. These disparities underscore the need for balanced development in physical infrastructure, such as water supply systems, and social infrastructure, including community engagement and education. SNA further explains the role of social capital in water management. Studies show that higher social ties and participation in formal institutions can significantly influence the success of poverty alleviation and water management efforts [30]. In rural areas, community-based organizations such as *HIPPAM* (Association of Drinking Water Users) and *PAMSIMAS* (Community-based Drinking Water Supply and Sanitation) have been effective in managing local water supply services, demonstrating strong social capital and contributing to higher happiness indices among residents [31]. In the research of Nti et al. [32], it was also explained that in several developing countries, many have water management systems that are managed by the community itself. Additionally, community participation in water conservation practices, such as well infiltration and reforestation, has been identified as important for sustainable water resource management [33]. The integration of these elements, with the existence of physical infrastructure as measured by the WPI, social capital as assessed through the SNA, and community-based management practices, is expected to form a comprehensive approach to achieving the goals of the Healthy Cities theory. This holistic strategy not only addresses the immediate need for safe water but also fosters long-term sustainability and community well-being.

3. METHODS

3.1 Research variables

The variables used in this study are variables adapted from several previous studies related to the WPI and SNA. These variables consist of resources, access, capacity, use, and environment (Table 1).

3.2 Data collection and sample

This research collects data through two types of surveys, namely secondary surveys and primary surveys. The secondary survey was conducted through a literature review and information from secondary data, while the primary survey was conducted through a questionnaire from the Pagak District community. Questionnaires were distributed to houses spread across Pagak District. Based on Malang One Regency Data for 2022, Pagak District has a total of 18,015 houses. The following are the results of sample calculations in this study using the Isaac-Michel (Table 2).

Table 1. Research variables

Purpose	Variables	Sub-Variables
Water poverty rate with WPI in Pagak District	Resources	• Groundwater availability • Availability of piped water
	Access to water	• Access to clean water • Access to *MCK* (a place for bathing and washing as well as serving as a lavatory (toilet)) ownership • Access to septic tank ownership (a tank, typically underground, in which sewage is collected)
	Capacity	• Education Level of the community • Public health level • Income distribution
	Use	• Domestic water utilization • Utilization of agricultural water
	Environment	• Vegetation cover
Calculating the level of community participation and density in Pagak District	Rate of participation	• Number of respondents • Number of institutions in the district • Community participation in institutions
	Density	• Respondents who have relationships with members of the institution • Respondents who do not have relationships with institutional members

Table 2. Isaac-Michel table

N	S			N	S			N	S		
	1%	5%	10%		1%	5%	10%		1%	5%	10%
10	10	10	10	280	197	115	138	2,800	537	310	247
15	15	14	14	290	202	158	140	3,000	543	312	248
20	19	19	19	300	207	161	143	3,500	558	317	251
25	24	23	23	320	216	167	147	4,000	569	320	254
30	29	28	27	340	225	172	151	4,500	578	323	255
35	33	32	31	360	234	177	155	5,000	586	326	257
40	38	36	35	380	242	182	158	6,000	598	329	259
45	42	40	39	400	250	186	162	7,000	606	332	261
50	47	44	42	420	257	191	165	8,000	613	334	263
55	51	48	46	440	265	195	168	9,000	618	335	263
60	55	51	49	460	272	198	171	10,000	622	336	263
65	59	55	53	480	279	202	173	15,000	635	340	266
70	63	58	56	500	285	205	176	20,000	642	342	267
80	71	65	62	600	315	221	187	40,000	563	345	269
85	75	68	65	650	329	227	191	50,000	655	346	269

90	79	72	68	700	341	233	195	75000	658	346	270
95	83	75	71	750	352	238	199	100,000	659	347	270
100	87	78	73	800	363	243	202	150,000	661	347	270
110	94	84	78	850	373	247	205	200,000	661	347	270
120	102	89	83	900	382	251	208	250,000	662	348	270
130	109	95	88	950	391	255	211	300,000	662	348	270
140	116	100	92	1,000	399	258	213	350,000	662	348	270
150	122	105	97	1,050	414	265	217	400,000	662	348	270
160	129	110	101	1,100	427	270	221	450,000	663	348	270
170	135	114	105	1,200	440	275	224	500,000	663	348	270
180	142	119	108	1,300	450	279	227	550,000	663	348	270
190	148	123	112	1,400	460	283	229	600,000	663	348	270
200	154	127	115	1,500	469	286	232	650,000	663	348	270
210	160	131	118	1,600	477	289	234	700,000	663	348	270
220	165	135	122	1,700	485	292	235	750,000	663	348	271
230	171	139	125	1,800	492	294	237	800,000	663	348	271
240	176	142	127	1,900	498	297	238	850,000	663	348	271
250	182	146	130	2,000	510	301	241	900,000	663	348	271
260	187	149	133	2,200	520	304	243	950,000	663	348	271
270	192	152	135	2,600	529	307	245	1,000,000	664	349	272

Source: [34]

Based on Malang Regency Data One Year 2022, Pagak District has a total of 18,015 houses. This research uses an error rate of 10% with an accuracy of 90%. So from a population of 18,015 houses, a sample of 267 houses was obtained. This study used a proportional random sampling technique to ensure that the sample selected reflects population variation in the proper proportions. Within the framework of social capital research that focuses on social interactions and relationships in society, it is important to obtain samples comparable to the population's composition. The following is the calculation of the sample proportion for each village in Pagak District (Table 3).

$$\text{Number of samples for each village} = \frac{\text{Number of houses in each village}}{\text{Total houses in district}} \times \text{Total number of samples}$$

Table 3. The samples proportion

Village	Total of Houses	Population	Proportion	Sample Number
Sumbermanjing Kulon		7,767	$\frac{7{,}767}{49{,}724} \times 18{,}015 = 2{,}814$	$\frac{2{,}494}{18{,}015} \times 267 = 42$
Pandanrejo		2,494	$\frac{2{,}494}{49{,}724} \times 18{,}015 = 904$	$\frac{904}{18{,}015} \times 267 = 13$
Sumberkerto		4,041	$\frac{4{,}041}{49{,}724} \times 18{,}015 = 1{,}464$	$\frac{1{,}464}{18{,}015} \times 267 = 22$
Sampol	18,015	5,891	$\frac{5{,}891}{49{,}724} \times 18{,}015 = 2{,}134$	$\frac{2{,}134}{18{,}015} \times 267 = 32$
Pagak		8,789	$\frac{8{,}789}{49{,}724} \times 18{,}015 = 3{,}184$	$\frac{3{,}184}{18{,}015} \times 267 = 47$
Sumberrejo		7,510	$\frac{7{,}510}{49{,}724} \times 18{,}015 = 2{,}721$	$\frac{2{,}721}{18{,}015} \times 267 = 40$
Gampingan		7,100	$\frac{7{,}100}{49{,}724} \times 18{,}015 = 2{,}572$	$\frac{2{,}572}{18{,}015} \times 267 = 38$
Tlogorejo		6,132	$\frac{6{,}132}{49{,}724} \times 18{,}015 = 2{,}222$	$\frac{2{,}222}{18{,}015} \times 267 = 33$
Total	**18,015**	**49,724**	**18,015**	**267**

Source: Analysis Results, 2024

3.3 Data analysis

The analysis techniques used in this research are WPI and SNA analysis. WPI is a tool used to measure vulnerability to water shortages by considering five main components: resources, access, capacity, use, and environment. This method was chosen because it provides a comprehensive picture of water availability and distribution, as well as factors that influence water access and use in the community. WPI helps identify areas most in need of intervention and improvement in water management. Meanwhile, SNA is an analytical method used to map and measure relationships and information flows between individuals, groups or organizations in a social network. SNA was chosen to analyze interactions and collaboration between various stakeholders in water management. By understanding the structure of social networks, research can identify key actors and communication patterns that are important in effective and sustainable water management. Data analysis in this research used Microsoft Excel software and the UCINET Version 6.774 application.

3.3.1 WPI

1) Resources

Resources are related to physical aspects that can be utilized by society, such as the availability of water in surface water sources (such as rivers, reservoirs and lakes) and in the ground (wells). The calculation of this variable adopts the Water Availability Index (WAI) approach, which compares the total availability of water in surface water sources, groundwater and piped water with the total population in an area [20]. The results of this calculation produce data related to water availability per capita which is expressed in m^3/capita/year.

2) Access

Access is a variable that is determined based on the availability and affordability of the population to clean water and sanitation. The access variable in this study uses three sub-variables, namely the number of households with access to clean water (piping), sanitation (private toilets) and waste (septic tanks). A percentage is determined for each sub-variable and the average value is determined to determine the value of the access variable.

3) Capacity

Capacity is a variable that reveals residents' ability to purchase and manage water. The capacity variable has four sub-variables, namely welfare level, education level, health level and regional income level. These sub-variables are calculated using their respective measuring tools, such as, the level of welfare is measured based on gross domestic product per capita, the level of public health is obtained through information on people who have experienced illnesses caused by water, such as dysentery, diarrhea, etc. The sub-variable of community education level is measured by knowing the number of pure community participation in pursuing a minimum of high school education. Then, the level of income in an area is measured using the Gini index (calculation of income distribution inequality).

4) Utilization

Utilization is a variable that describes the condition of water used by the community with sub-variables, namely water use for household purposes and water use for agricultural purposes [35]. Domestic water use generally ranges from 0 to 320 liters/capita/day, while use for agricultural purposes is obtained by comparing the area of irrigated land with the total area of agricultural land.

5) Environment

Environment is a variable that describes the level of maintenance of ecological integrity related to water resources [36]. Environment has two sub-variables, namely water quality and vegetation cover. Water quality is determined based on the water quality found in Malang Regency. Measurement of domestic water quality uses Minister of Environment Decree No. 115 of 2003 concerning Guidelines for Determining Water Quality Status using the STORET method, which compares water quality data with drinking water quality standards. Meanwhile, vegetation cover is calculated by calculating the percentage of green open space area in the total area of the research area.

The WPI calculation value is obtained by adding up the five variables which have been multiplied by the calculated weight and divided by the number of calculated weights used. The weight values used are determined based on the characteristics of the research area. The weights and formula for calculating the WPI are written as follows (Table 4).

Table 4. WPI variable weights

No.	**Regional Characteristics**	**Variable Weights**				
		Resource	**Access**	**Capacity**	**Use**	**Environment**
1.	Agriculture, Industry, and Social	1	2	2	3	1
2.	Social	1	2	2	1	1
3.	Environmental and social	1	2	2	1	2
4.	Industry and agriculture	1	2	2	2	1

Source: [37]

The WPI is a method used to identify water poverty utilizing the availability of clean water in the Malang Regency area using the following calculation formula.

$$WPI = \frac{wrR + waA + wcC + wuU + weE}{wr + wa + wc + wu + we}$$

Source: [38]

After knowing the WPI value based on the calculation above, then the value is standardized into a benchmark scale with the level of water poverty and standardization of water resource security values based on standards developed by the Wallingford Center for Ecology and Hydrology (PEH) as in the following table (Table 5) [39].

Table 5. WPI category

Scale	**Water Poverty Levels**	**Scale**	**Condition**
75-85	Very low	>62	Safe
65-75	Low		
55-65	Quite low	56-61.9	Low security
45-55	Moderate	48-55.9	Not safe
35-45	Quite tall	35-47.9	Critical
25-35	Height		
15-25	Very high		

Source: [39]

In calculating the WPI equation, variable weights are used to provide values that are relatively more appropriate or relevant between the value of each variable and the conditions of the study area, considerations related to issues, local policies, and things that are considered important in the calculation of each variable to determine the weight criteria that will be used [39]. In this study, the variable weights used are based on regional characteristics with environmental and social functions with a weight value of 1-2-2-1-2.

3.3.2 SNA

SNA is a community measurement method used to measure patterns of community structure and collaboration between individuals or organizations. The types of SNA methods used include the level of participation (RoP) and level of density (density).

1) Participation Level (RoP), The degree of participation refers to the extent to which individuals or entities in a social network engage in interactions or relationships with other actors. A high level of participation indicates an actor is actively involved in a social network with many connections or relationships [24].

2) Density describes the level of connectedness between members in a social network. High density indicates that many network members are connected, while low density indicates remoteness or isolation in the network [20, 24, 26].

3.4 Study context

Pagak is one of the 33 sub-districts in Malang Regency. Astronomically, Pagak District is located between 112.2966 to 112.3312 East Longitude and 8.1146 to 8.1827 South Latitude. Referring to the potential data for Pagak District, the geographical location of some villages in Pagak District is plain. Another part of the geographical location is a slope, with the village topography in Pagak District being flat and hilly. The total area of Pagak District is around 82.46 km^2 or around 3.03% of the total area of Malang Regency. The territorial boundaries of Pagak District are as follows:

To the North: Kepanjen District and Sumberpucung District
To the East: Bantur District
To the South: Donomulyo District and Bantur District
To the West: Donomlyo District and Kalipare District

The Pagak District consists of eight villages, including Sumbermanjingkulon Village, Pandanrejo Village, Sumberkerto Village, Sempol Village, Pagak Village, Sumberejo Village, Gampingan Village, and Tlogorejo Village.

4. RESULTS

4.1 Water Poverty Index

4.1.1 Resources

The calculation of the availability value is a combination of several sub-variables between the availability of well water and the availability of piped water. Water use in Pagak District is served by two sources of clean water, namely *HIPPAM*, *PAMSIMAS,* and well water. The following is a calculation of the value of resources in the Pagak District (Table 6).

Table 6 shows that resource variables can be calculated by the value of water availability, which is divided into surface water availability, groundwater availability, and piped water availability. For daily needs, most people in Pagak District use piped water and groundwater in the form of well water with a well depth of 25 meters. Still, in Sempol Village, water availability is at a depth of 15 meters. The availability of piped water is calculated from the reservoir's water availability.

4.1.2 Access

The value of the access variable is a calculation of several sub-variable values of access to clean water, access to sanitation, and access to healthy sanitation (ownership of septic tanks). The following is the calculation result of the access variable (Table 7).

Table 6. Water Poverty Index resource (wrR) of Pagak District

Village Name	Surface Water Availability (m)	WPI Value	Groundwater Availability (m)	WPI Value	Availability of Piped Water (m^3/capita/year)	WPI Value	WAI Value
Gampingan	0	0	25	75	0	0	25
Pandanrejo	0	0	30	75	0	0	25
Sumbermanjing	0	0	25	75	343,088	100	58.3
Sempol	0	0	15	100	0	0	33.3
Crow	0	0	25	75	84,856	100	58.3
Sumberkerto	0	0	25	75	51,279	100	58.3
Tlogorejo	0	0	25	75	0	0	25

Source: Analysis Results, 2024

Table 7. Water Poverty Index access (waA) of Pagak District

Village Name	Sample House	TAPS	Access to Clean Water	Sanitation Access	Septic Tank Access	WPI Value	
Gampingan	38	0	0%	100%	97%	65.67%	65.67
Pandanrejo	13	6	46%	92%	92%	76.82%	76.82
Sumbermanjing Kulon	42	20	48%	95%	95%	79.27%	79.27
Sempol	32	0	0%	100%	97%	65.67%	65.67
Sumberejo	40	0	0%	98%	95%	64.17%	64.17
Crow	47	26	55%	100%	98%	84.44%	84.44
Sumberkerto	22	0	0%	100%	95%	65.00%	65.00
Tlogorejo	33	1	3%	55%	55%	37.68%	37.68

Source: Analysis Results, 2024

Table 7 shows the calculation of access variables in each village in the Pagak District, which consist of access to clean water, sanitation, and healthy waste. Access to clean water has the highest value of 55%. In contrast, four villages do not have access to clean water at all, which means that some people in Pagak District have not even been served by clean water, both piped and non-piped. In contrast, for access to sanitation and healthy waste (septic tank ownership), the majority of people who *MCK* and septic tank ownership have served are only in Tlogorejo Village whose sanitation access is still not good, namely: there are 45% of underserved communities with access to proper sanitation.

4.1.3 Capacity

The calculation of capacity value is obtained from the percentage value of health level, the percentage value of education level, and income inequality value (Gini index). The following is a calculation of the capacity value (Table 8).

Table 8. Water Poverty Index capacity (wcC) of Pagak District

Village Name	Health Level WPI Value	WPI Value of Education Level	Gini Index WPI Value	WPI Value
Gampingan	30	66	64	53.33
Pandanrejo	46	63	64	57.67
Sumbermanjing Kulon	48	82	64	64.67
Sempol	36	70	64	56.67
Sumberejo	40	75	64	59.67
Crow	55	83	64	67.33
Sumberkerto	53	66	64	61.00
Tlogorejo	40	61	64	55.00

Source: Analysis Results, 2024

In Table 8, it is known that the level of public health in Pagak District is mostly low, where the highest health level in Pagak Village is 55%. While in Gampingan Village is the lowest village for its health level, which is 30%, which means there are 70% of residents who have experienced illnesses caused by clean water, such as diarrhea. The lowest level of public education is in Pandanrejo at around 63%, which means that there are still 37% of people who do not participate in compulsory education for 12 years or do not graduate from high school. The value of the Gini index illustrates the inequality of income distribution, and the value of the Gini index in the Pagak District is 64%.

4.1.4 Use

The value of use calculation is obtained from calculating the value of domestic needs, the average use value, the value of existing domestic water use, and agricultural land use. The following is a calculation of the usage value in Pagak District (Table 9).

Table 9 shows that the average domestic demand is lower when compared to standard water needs, which means that people use water not excessively and are still limited to standard water needs. For the calculation of agricultural utilization obtained from the irrigation area divided by the cultivation area.

4.1.5 Environment

Environmental variables are calculations obtained from sub-variables of water quality and percentage of vegetation cover. The water quality value of each village is assessed based on the physical and non-physical water quality. Physical water quality is seen from the parameters of smell, taste, and sediment. The following is the result of calculating the value of the Environment in Pagak District (Table 10).

Table 10 shows that the highest vegetation cover area in Sumbermanjing Kulon Village is 34%, and the lowest in Sumberkerto Village and Tlogorejo Village is 12%. The value of vegetation cover can be seen in each village's Green Open Space Area. Green Open Space Areas can be parks, road medians, or river boundaries. The WPI value on the environment variable describes a low WPI value. The WPI value of the lowest environmental variable in Sumberkerto Village and Tlogorejo Village with a WPI value of 12. The highest environmental variable WPI value in Sumbermanjing Kulon Village is 34.

Table 9. Water Poverty Index use (wuU) Pagak District

Village Name	Population	Domestic Water Needs (L/day)	Average Usage n (L/Soul Day)	Existing/ Standard	WPI Water Usage	Area of Agricultural Land (hectare)	Utilization of Wet Agricultural Land (hectare)	Percentage of Agricultural Land Utilization	WPI Value Agriculture	WPI Use
Gampingan	7,767	1,165,050	38,368.482	0.03	99.97	495	456	6%	6	52.98
Pandanrejo	2,494	374,100	119,489.976	0.32	99.68	260	220	3%	3	51.34
Sumbermanjing Kulon	4,041	606,150	73,746.1024	0.12	99.88	1,107	1,068	13%	13	56.44
Sempol	5,891	883,650	50,586.9971	0.06	99.94	870	831	10%	10	54.97
Sumberejo	8,789	1,318,350	33,906.9291	0.03	99.97	1,185	1,146	14%	14	56.99
Crow	7,510	1,126,500	39,681.4913	0.04	99.96	48	40	0.5%	0.5	50.23
Sumberkerto	7,100	1,065,000	41,972.9577	0.04	99.96	233	194	2%	2	50.98
Tlogorejo	6,132	919,800	48,598.8258	0.05	99.95	36	29	0.4%	0.4	50.17

Source: Analysis Results, 2024

Table 10. Water Poverty Index environment (weE) Pagak District

Village Name	Green Open Space Area (Hectare)	Area (Hectare)	Percentage of Vegetation Land Cover	WPI Value (Green Open Space Area)	WPI Value
Gampingan	330	1,094	30%	30	30
Pandanrejo	153	483	32%	32	32
Sumbermanjing Kulon	576	1,706	34%	34	34
Sempol	339	1,469	23%	23	23
Sumberejo	454	1,784	25%	25	25
Crow	131	647	20%	20	20
Sumberkerto	102	832	12%	12	12
Tlogorejo	28	228	12%	12	12

Source: Analysis Results, 2024

The calculation of each variable of the WPI value is obtained from 5 variables, which will later be calculated using the multiplication of the weight value of each variable. The weight is seen from the characteristics of the study area in the table, the value of the weight of resource, access, capacity, use and environment is selected as 1-2-2-3-1. The calculation of the WPI is then classified into poverty conditions in Table 11. The following is the result of calculating the value of the WPI in Pagak District.

The results of the calculation of the Water Poverty Index in the Pagak District area come from five components with each component value shown in a radar diagram (pentagram). Based on the calculations that have been done, the overall WPI of Pagak District is 74.08. Therefore, Pagak District is classified as a low level of water poverty with safe water resource conditions. The following is a pentagram of several villages in Pagak District (Figure 1).

Based on the figure, it can be seen that the calculation of the WPI is calculated using five variables. Where the lowest WPI value is in Tlogorejo Village, which is 44.51, this is significantly influenced by 2 variables, namely access and environment variables. The access variable shows the lowest value or is included in the critical classification among other villages because the percentage of piped water use is the lowest and the percentage of septic tank ownership that is according to standards is also still relatively low (Table 11).

Table 11 is the result of WPI calculation in each village with the lowest calculation result found in Tlogorejo Village which is 44.51 and the highest in Sumbermanjing Village which is 61.64. The WPI value is calculated by multiplying the different weights in each variable. The lowest variable value is in the environmental variable because this variable considers the area of Green Open Space Area in the study area. Several villages have not been facilitated by Green Open Space Area. The value of access has a relatively low value, this is because water access in Pagak District is still relatively low both in terms of access to clean water through piping (*PDAM PAMSIMAS*, and *HIPPAM*) and from groundwater (wells). *PDAM* is a local drinking water company whose main service area is for urban communities. In this research, *PDAM*, *PAMSIMAS*, and *HIPPAM* serve villages in Pagak District.

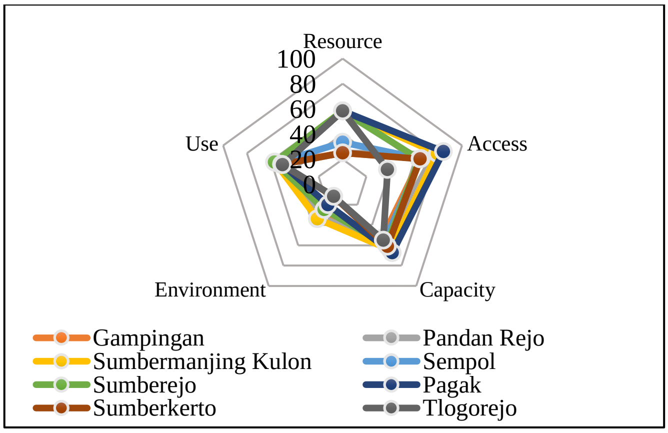

Figure 1. Water Poverty Index of Pagak District
Source: Analysis Results, 2024

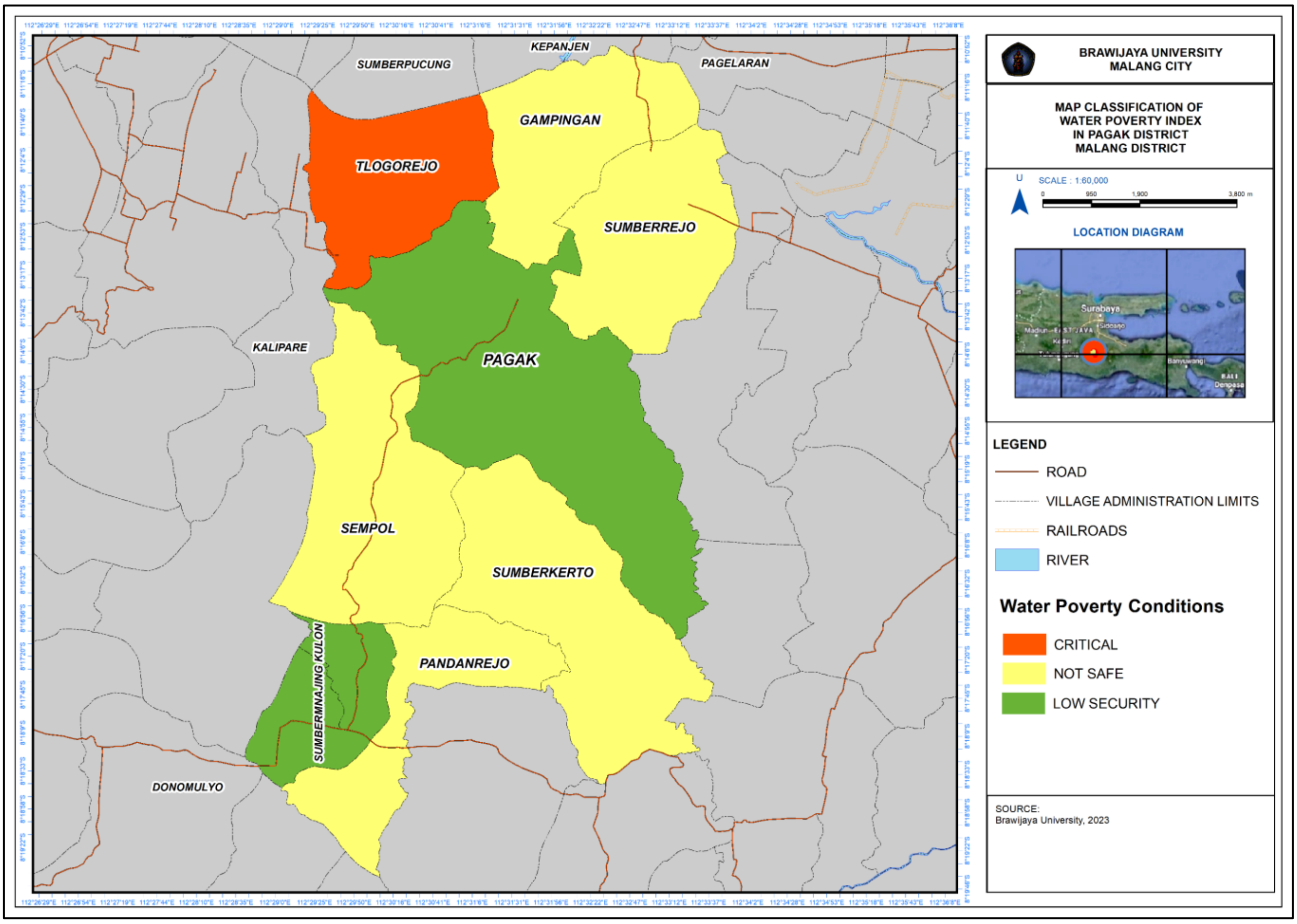

Figure 2. Classification of Water Poverty Index in Pagak District
Source: Analysis Results, 2024

Table 11. Water Poverty Index of Pagak District

Village Name	Resources	Access	Capacity	Environment	Use	WPI	Conditions of Poverty
Gampingan	25	65.67	53.33	30.00	52.98	49.87	Insecure
Pandanrejo	25	76.82	57.67	32.00	51.34	53.58	Insecure
Sumbermanjing kulon	58.33	79.27	64.67	34.00	56.44	61.64	Low security
Sempol	33.33	65.67	56.67	23.00	54.97	51.37	Insecure
Sumberejo	58.33	64.17	59.67	25.00	56.99	55.62	Insecure
Pagak	58.33	84.44	67.33	20.00	50.23	60.29	Low Security
Sumberkerto	25	65	61.00	12.00	50.98	48.87	Insecure
Tlogorejo	58.33	37.68	55.00	12.00	50.17	44.51	Critical

Source: Analysis Results, 2024

Meanwhile, *HIPPAM* and *PAMSIMAS* is a community water management association in Pagak District whose service coverage includes rural communities with simple water piping network techniques. The value of WPI with a critical classification, if left continuously, will certainly have an impact on the availability of clean water in Pagak District (Figure 2).

4.2 Social Network Analysis

SNA is an analysis used to measure social relations within a society's institutions. The SNA analysis in this research was carried out on the community in Pagak District with a total of 267 respondents. The results of the SNA analysis in this study interpret the level of community participation and community density in Pagak District. The following is community participation in institutions (Figure 3).

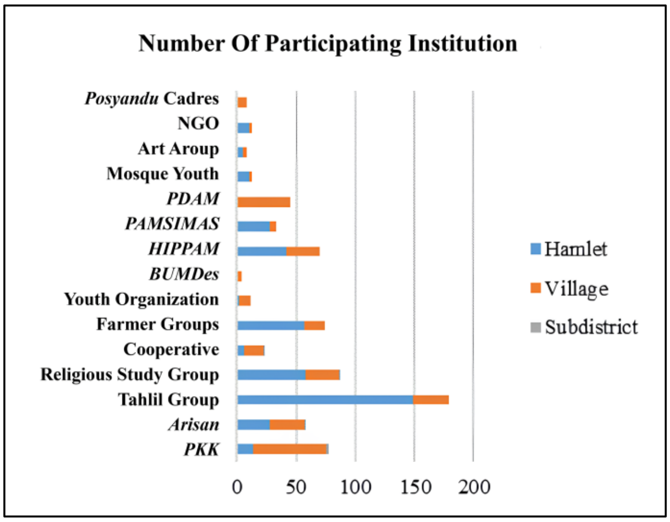

Figure 3. Table diagram of community participation in institutions in Pagak District

Source: Analysis Results, 2024

Based on data on community participation in institutions (Figure 3), it can be seen the number of people participating in each institution in each village in Pagak District. There are 15 types of institutions in Pagak District spread across 8 villages. These institutions consist of *PKK* (Family Welfare Program), *Arisan* (Regular Social Gathering), *Tahlil* Group, Religious Study Group, Cooperative, Farmer Groups, Youth Organization, *BUMDes* (Village-Owned Enterprise), *HIPPAM* (Association of Drinking Water Users), *PAMSIMAS* (Community-based Drinking Water Supply and Sanitation), *PDAM* (Municipal Waterworks), Mosque Youth, Art Aroup, NGO, and *Posyandu* (Integrated Service Post) cadres. Furthermore, the participation rate or RoP and community density in each village in Pagak District are calculated. The following are the results of the calculation.

4.2.1 Rate of participation

RoP or participation level analysis was carried out to determine how much participation the Pagak District community has in an institution. The results of the RoP analysis interpret the high level of community participation, and the higher the participation, the better. The initial step in analyzing participation levels is to divide classes and classify them. The interval in each class is calculated by subtracting the maximum number of respondent participation from the minimum number of respondent participation. Then, the results are divided into three classes, with grades classified into three classes: high, middle, and low. The following are the class intervals used in this research (Table 12).

Table 12. Distribution of RoP Class Intervals in Pagak District

No	Village	Class Intervals	Classification
1	Gampingan	1-2.667	Low
		2.668-5.334	Middle
		5.335-8	High
2	Pandanrejo	1-3	Low
		4-6	Middle
		7-9	High
3	Sumbermanjing kulon	1-2.333	Low
		2.334-4.666	Middle
		4.667-7	High
4	Sempol	1-3	Low
		4-6	Middle
		7-9	High
5	Sumberejo	1-3	Low
		4-6	Middle
		7-9	High
6	Pagak	1-2.667	Low
		2.668-5.334	Middle
		5.335-8	High
7	Sumberkerto	1-2	Low
		3-4	Middle
		5-6	High
8	Tlogorejo	1-1.667	Low
		1.668-3.334	Middle
		3.335-5	High

Source: Analysis Results, 2024

The maximum number of respondents participating in this research is the number of institutions the community participates in in each village in Pagak District. Meanwhile, the minimum number of respondent participation is 0, this is because there is no obligation for the public to participate in the Institution. The people of Pagak District voluntarily participate and join the institution. The next step is to calculate the participation rate using the formula used, namely:

Participation Level = Number of Diagonal Matrix / Number of Respondents

Based on this calculation formula, the RoP value for eight villages in Pagak District can be calculated as follows (Table 13).

Table 13. Rate of participation values

No.	Village	Class Intervals	Classification
1	Gampingan (N=38)	2.53	low
2	Pandanrejo (N=13)	3	low
3	Sumbermenjing Kulon (N=42)	3.81	middle
4	Sempol (N=32)	2.81	low
5	Sumberejo (N=40)	2.23	low
6	Pagak (N=47)	3.04	middle
7	Sumberkerto (N=22)	1.82	low
8	Tlogorejo (N=33)	1.39	low

Source: Analysis Results, 2024

Based on the RoP values in the eight villages in Pagak District, it can be seen that the classification of participation levels in Pagak District is that two villages have a Middle classification, and six villages have a low classification. Villages included in the Middle classification are Pagak Village and Sumbermanjing Kulon Village. The villages included in the low classification are Gampingan Village, Pandanrejo Village, Sempol Village, Sumberkerto Village, Sempol Village, Tlogorejo Village, and Sumberejo Village. The classification is based on the number of active institutions in the village, namely Sempol Village, Sumberejo Village, and Pandarejo Village consist of 9 types of institutions; Pagak Village and Gampingan Village consist of 8 institutions; Sumbermanjing Kulon Village 7 institutions; Sumberkerto Village 6 institutions, and Tlogorejo Village 5 institutions.

4.2.2 Density

Density analysis was carried out to determine the relationship density between respondents in Pagak District. Density is interpreted as the average number of activities occurring by each institution. The density value ranges from 0 to 1, and a maximum value of 1 indicates that at least 100% of the population in an area has one or more equivalent memberships in existing institutions. This reflects the high density of relationships in society. Density can be divided into three categories: low, medium, and high. The density value class interval is obtained from the highest density value, namely 1, minus the lowest density value, namely 0, then divided by three because it has three classifications: low, medium, and high. Density calculations in this research were carried out using UCINET 6 software. The initial step was to prepare an institutional matrix for each village in Pagak District. The following is the class interval for density analysis in the Pagak District (Table 14).

This calculation was carried out in eight villages in Pagak District, resulting in different density values. The density value in Pagak District is in the medium to high range. The following are the results of density calculations in Pagak District (Table 15).

Based on the results of density calculations, it can be seen that the highest density value is in Sumbermanjing Kulon Village, with a value of 0.945 or 94.5% with a high classification, and the lowest density is in Tlogorejo Village, with a value of 0.353 or 35.3% with a Middle classification. Villages included in the high classification are Gampingan Village, Pandanrejo Village, Sumbermanjing Kulon Village, Sempol Village, Sumberkerto Village, Sumberejo Village, and Pagak Village. Meanwhile, villages that have a medium classification include Tlogorejo Village.

Table 14. Density value classification

No	Class Intervals	Classification
1	0.00-0.333	Low
2	0.334-0.666	Middle
3	0.667-1.000	High

Source: [30]

Table 15. Pagak District density

No	Village	Density Value	Classification
1	Gampingan	0.855	High
2	Pandanrejo	0.833	High
3	Sumbermenjing Kulon	0.945	High
4	Sempol	0.834	High
5	Sumberejo	0.677	High
6	Pagak	0.789	High
7	Sumberkerto	0.805	High
8	Tlogorejo	0.353	Middle

Source: Analysis Results, 2024

5. DISCUSSIONS

Based on the results of the Water Poverty Index analysis and Social Network Analysis, findings were obtained by comparing the two analyses to determine critical clean water areas in the Pagak District. WPI is an analysis that measures the water poverty level in Pagak District. Meanwhile, SNA is an analysis that measures the level of participation and density of community relations in existing institutions in Pagak District. Based on Table 11, the WPI results in the Pagak District are seen through the resource, access, capacity, environment, and use aspects. WPI results show that five villages in Pagak District have conditions of unsafe poverty. Meanwhile, 2 villages have low security, and one has a crisis category. Villages in Pagak District that have a low-security category are Sumbermanjing Kolon Village and Pagak Village. Meanwhile, Tlogirejo Village has a WPI score in the crisis category.

The WPI value is calculated by multiplying the different weights for each variable. The lowest value is found in the environmental variable because this variable considers the area of Green Open Space in the study area. Several villages have not been facilitated with adequate green open space areas, thus reducing the score for this variable. The value of water access in Pagak District is also low due to a lack of access to clean water through pipes (*PDAM*, *PAMSIMAS*, and *HIPPAM*) or from groundwater (wells). *PDAM*, which usually serves urban communities, and *HIPPAM* and *PAMSIMAS*, which manages water using a simple pipe network in villages, are still unable to meet clean water needs in several areas adequately.

Meanwhile, based on the SNA analysis, it can be seen in Table 13 and Table 15, which shows the level of community participation in institutions and the density or density of relationships between communities. Sumbermanjing Kulon Village is a village in Pagak District that has the highest participation rate with a score of 3.81. This means that in general, the people in Sumbermanjing Kulon Village adhere to 4 institutions. The institutions in Sumbermanjing Kulon Village are the *PKK* Institution, *Arisan*, *Tahlil* group, religious study group, cooperatives, farmer groups, and *HIPPAM*. The institution most frequently participated in by the people of Sumbermanjing Kulon Village is the *Tahlil* group. Meanwhile, the village in Pagak District with the lowest participation rate is Tlogorejo Village, which has a value of 1.39. This means that the people of Tlogorejo Village usually only participate in 1 institution. The institutions in Tlogorejo Village consist of *PKK, Arisan, Tahlil* Group, farmer groups, and mosque youth. The institution that the people of Tlogorejo Village most widely follow is the Tahlil Association. Then, the density calculation results show that the highest density value is in Sumbermanjing Kulon Village with a value of 0.945 or 94.5% with a high classification, and the lowest density is in Tlogorejo Village with a value of 0.353 or 35.3% with a medium classification. Based on these results, a comparison of the SNA values and WPI values was carried out. The following are the comparison results (Table 16).

Table 16. Comparison of rate of participation values and WPI Values

No.	Village	Classification of Rate of Participation Values	Classification Density Value	WPI Value Calcification
1	Gampingan	Low	High	Insecure
2	Pandanrejo	Low	High	Insecure
3	Sumbermenjing kolun	Middle	High	Low Security
4	Sempol	Low	High	Insecure
5	Sumberejo	Low	High	Insecure
6	Pagak	Middle	High	Low Security
7	Sumberkerto	Low	High	Insecure
8	Tlogorejo	Low	Middle	Critical

Source: Analysis Results, 2024

Based on the comparison of the values of the two analyses in Table 16, it can be seen that Sumbermenjing Kolun Village and Pagak Village are the villages that have the best levels of participation, density, and WPI. Meanwhile, Tlogorejo Village is the village with the lowest participation rate, density, and WPI, with a low participation rate, medium density, and crisis WPI. SNA provides insight into interactions and relationships between communities and institutions in the Pagak District. Findings show that the level of participation and density of community relations varies between villages. Villages with lower WPI scores tend to have less strong social networks, which means community participation in water management is still low. This hampers the effectiveness of water distribution and management, exacerbating the shortage of clean water. By integrating the results of WPI and SNA, this research can identify the most critical villages in terms of availability and access to clean water and evaluate the level of community participation in water management. Tlogerejo Village, with a WPI score in the crisis category, shows that apart from facing a lack of clean water, this village may also have a weak social network. Therefore, interventions in this village must include improving water infrastructure as well as empowering communities to increase participation in water management.

These findings align with several previous studies that highlight the importance of the relationship between the WPI and SNA in understanding and improving community social capital for effective water management. The WPI, which measures socioeconomic aspects of water scarcity, can identify areas requiring improvements in resources, access, capacity, use, and environmental quality, as seen in studies of the Beheshtabad Basin and Karoo River in Iran [40, 41].

Social capital, which includes trust, cooperation, social network cohesion, leadership roles, and conflict resolution, plays an important role in water management. An example is a traditional water reservoir in Mazandaran province, Iran, where local leaders facilitated cooperation and conflict resolution, although with limited long-term success [42]. In Indonesia, *HIPPAM* in rural areas such as Sumbermujur Village show strong social ties and high social capital, which contribute to better water management and a higher happiness index among residents [30].

Integrating WPI with SNA can provide a comprehensive framework for assessing and improving water management practices by leveraging social capital. This integration ensures that water management strategies are not only technically effective but also socially sustainable, addressing both the physical and social dimensions of water scarcity. Thus, good WPI, when combined with high community social capital as analyzed through SNA, can significantly improve water management practices, ultimately improving water access and overall community well-being [30, 40-42].

In facing the problem of water poverty, it is not enough to just focus on physical infrastructure development. It is important to pay attention to social conditions in order to improve people's knowledge, skills and information [37]. Social capital is the social character of society which is described by social networks, norms and beliefs due to the existence of shared values in society that form capital [43]. Social capital can come from social networks formed in society which are supported by norms and relationships of reciprocity and mutual trust [44-46]. Information exchange, cooperation, and trust between neighbors can contribute to the building of social capital [47-51].

Therefore, good social conditions are key in efforts to reduce poverty. To achieve this, it is necessary to strengthen social capital through social networks between community members and their affiliations with existing institutions. A low value on the WPI indicates the need for efforts to eradicate water poverty, both through physical and social development [32]. In line with this, Tlogorejo Village, Pagak District, based on the results of the WPI and SNA analysis, is the village with the lowest score. So it is necessary to develop clean water management in this area, which is expected to overcome the problems of clean water management in Pagak District. In the research of Bisung et al. [52], stated that to increase access to clean water, not only social capital is needed. These findings support the view that environmental challenges in marginalized communities are caused by structural disparities in resource distribution, rather than by a lack of social capital [53]. However, the existence of social capital can make it easier for marginalized communities to improve their welfare, especially in terms of access to clean water. Research by Yudiatmaja et al. [54] also emphasized that the principle of mutual cooperation as social capital for local Indonesian communities positively influences social cohesion and the development process. Social capital, which involves norms, networks, values, togetherness and mutual cooperation, also plays a key role in determining the water resources management process.

In more detail, the WPI value in the access aspect shows a low level due to low access to water through the pipe system in Pagak District. This indicates that there are problems that require special attention to be corrected. It is important to increase water access to every household by providing direct piped water connections to guarantee access to clean water both in terms of quantity and quality. This is in line with the Sustainable Development Goals (SDGs), especially pillars 1 and 6, which relate to alleviating water poverty. It should be remembered that development is not only related to physical infrastructure but also requires strengthening social capital to strengthen communities and their institutions [32]. The majority of institutions in Pagak District are at the village level, social capital plays an important role in community initiatives to achieve access to clean water. This initiative is reflected in the establishment of a clean water management institution in Pagak District.

Bonding social capital describes close relationships between individuals who have similar backgrounds, such as family, close friends, or neighbors, while bridging social capital involves strong ties with distant friends, coworkers, and colleagues [55]. Bukachi et al. [56] in their research on access to clean water show that community social capital is reflected in the way they help each other in utilizing water sources in other areas through the principle of mutual cooperation. In line with these findings, residents of Pagak District obtain clean water through a pipe system such as *HIPPAM* and *PAMSIMAS*, which is managed by each village. However, residents who live in locations further from clean water sources can utilize *HIPPAM* and *PAMSIMAS* facilities located in closer neighboring villages. This shows that there is a community initiative to work together in managing clean water in each village, with the aim that all communities in Pagak District can easily access clean water. Community social capital allows for greater cooperation between individuals and creates informal networks, because social capital can increase the sharing of risks and opportunities in the community, including in terms of water distribution [57, 58].

6. CONCLUSIONS

The conclusions of this research are as follows:

1) The WPI is assessed by calculating the level of Water Poverty which involves 5 variables, namely resources, access, capacity, use and environment. Based on the results of calculating the level of clean water poverty in Pagak District, the lowest value was in Tlogorejo Village at 44.51 in the critical category and the highest was in Sumbermanjing Village at 61.64 in the low security category.
2) Calculation of the level of community participation in Pagak District reflects the extent of community involvement in institutions. The participation rate in Pagak District is relatively low, namely Tlogorejo Village with a value of 1.39. This means that the people of Tlogorejo Village usually only participate in one institution. Density analysis is used to measure density between respondents, and the lowest density value is in Tlogorejo Village with a value of 0.353 or 35.3% with a safe classification.

The results of the SNA analysis show that the level of participation and density of community relations varies between villages in Pagak District. Villages with low WPI scores tend to have weak social networks, hampering the effectiveness of water distribution and management. The integration of WPI and SNA helps identify villages that are most critical in terms of availability and access to clean water and evaluate community participation. This combination provides a comprehensive framework for improving water management by leveraging social capital, ensuring technically effective and socially sustainable strategies. As a result, good WPI and high social capital can significantly improve water access and community welfare.

These findings make important contributions to water resources management and community engagement theory and practice. Theoretically, this research confirms the importance of WPI and SNA for measuring water poverty and social participation. These results strengthen the understanding that water poverty is related to physical, social, and institutional aspects that influence water distribution and access. Practically, these findings guide local governments and local organizations to develop effective policies for managing water resources and increasing community participation.

Based on research findings, it is recommended that local governments focus on building clean water networks in critical villages such as Tlogorejo Village, as well as expanding the *PDAM, HIPPAM,* or *PAMSIMAS* pipe networks. The conservation of green areas must be increased to help absorb water and maintain environmental quality, and reservoirs must be created in villages to collect rainwater during the dry season. Education and outreach programs regarding the importance of community participation in water management must be encouraged through workshops, seminars, or training. Strengthening local institutions, such as forming and strengthening water management community groups like *HIPPAM* and *PAMSIMAS*, is also important. Regional governments can provide subsidies or incentives to villages that have succeeded in improving access and quality of clean water, as well as giving awards to villages that show significant improvements in participation and management of clean water. An integrated monitoring system must be implemented to periodically measure the condition of clean water and the level of community participation, as well as carry out regular assessments of the effectiveness of implemented policies and programs. These steps are expected to significantly improve access to clean water and the quality of life for the people of Pagak District.

This study has several limitations that may affect the results and interpretation of the findings. The data used only covers a certain time period, so it does not take into account dynamic changes that may occur. The limited research focus on Pagak District means that the findings may not be generalizable to other areas with different conditions. This limitation can affect the validity and reliability of research results. Therefore, further research with a broader scope and more comprehensive methods is needed to confirm and expand these findings.

Future research should expand geographic coverage and samples to gain a more comprehensive understanding of water poverty and community participation in various contexts. Further research could focus on developing and implementing innovative technologies for clean water management, as well as exploring the social and economic factors that influence community participation in water resources management. In this way, it is hoped that there will be a sustainable increase in access to clean water and community welfare in areas affected by water poverty.

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