Strategy for Realizing Regional Rural Water Security on Tropical Peatland

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Abstract: Fulfilling the need for clean water and proper sanitation is, globally, a basic human requirement, and Indonesia is no exception. Clean water and adequate sanitation are the sixth goal of the Sustainable Development Goals (SDGs), and targets include to ensure the availability of clean water and sustainable sanitation for all by 2030. The achievement of targets in water supply and sanitation in Indonesia is still lagging behind other fields. There are differences in the ease of obtaining access to clean water sources in urban and rural areas, especially for rural communities living on peatlands who experience issues in being provided with clean water. The difficulty is that, even though the amount of available water is relatively large, its quality is low. Barriers to the equitable distribution of services by the government to the entire community are caused by the limited availability of funding, the geographical conditions of scattered settlements, and the limited capacity of human resources. As a result of this problem, it is necessary to formulate a management strategy for providing access to clean water and sanitation for rural communities on peatlands. This research uses the case-study method. The management strategy was formulated on the basis of the environmental and socioeconomic conditions of the community. This method was used to test the effectiveness of the formulated strategy in realizing water security on peatlands in the village of Wajok Hilir. The resulting management strategy can be applied to other villages that have the same land characteristics. The strategy to realize water security for rural communities on peatlands is a self-service strategy. The implementation of the self-service strategy needs to be supported by infrastructure in the form of peat water treatment plant buildings, wells drilled to aquifer depths, and canal blocking to control the groundwater level in peatlands. The management strategy is carried out with community participation, considering that peatlands are a potential water source to meet clean water needs and achieve sustainable water security targets. Efforts to implement the self-service strategy are carried out with these methods: (1) socialization carried out in an integrated manner, (2) infrastructure development as a pilot project, (3) providing knowledge about infrastructure operations, (4) providing temporary assistance to the community, and (5) providing material supplies so that rural communities that are partners can become pioneers of similar movements.

Keywords: water security; peat water; peatlands; SDG 6; rural; water management strategy

1. Introduction

Fulfilling the need for clean water and proper sanitation is, globally, a basic human requirement. Clean water and adequate sanitation comprise the sixth goal of the Sustainable Development Goals (SDGs), which aims to ensure the availability of clean water and sustainable sanitation for all by 2030, so that water security can be realized. Unfortunately, in some parts of the world, water and sanitation needs are not fully satisfied [1]. Water security is defined as the ability of the community to maintain sustainability in meeting
water needs, both in sufficient quantities and to meet health standards to maintain livelihoods, welfare, and socioeconomic development, to guarantee protection against water pollution and disasters related to water, and to preserve natural ecosystems [2,3].

As many as 1.8 billion people do not have access to safely managed clean water, and as many as 2.4 billion people do not have access to proper sanitation. This water scarcity affects at least 40% of the global population and is projected to continuously increase [4], including in Indonesia. There are enough water sources on Earth to meet these basic needs. However, several factors cause the scarcity of clean water, such as increasing water demand, decreasing water resources, and increasing water pollution driven by population growth and rapid economic growth [5]. Other causes that affect the difficulty of gaining access to clean water include a lack of knowledge, and level of education [6]. The poor quality of available water and weak economic conditions or inadequate infrastructure mean that, globally, there are still many people who do not have access to clean water [7].

The achievement of targets in clean water supply and sanitation in Indonesia is still lagging behind other fields [8]. There are differences in the ease of obtaining access to clean water sources in urban and rural areas. Access to clean water sources can be illustrated by the higher percentage of households with access to drinking water and proper sanitation, by residence, in urban areas, reaching 95.6% in 2020; in rural areas, this is only 81.2% [9]. The diversity of geographical conditions, the availability of natural resources, and the significant disparity between rural and urban areas are factors that determine the accessibility of public services, such as drinking water and proper sanitation [10,11]. Issues of social and economic conditions, the equitable distribution of education, and differences in existing institutional bodies in urban and rural areas can influence the equitable distribution of clean water and proper sanitation for the community [12,13].

West Kalimantan is one of the provinces located on the island of Kalimantan. West Kalimantan is located in the western part of the island of Borneo, or between the lines 2°08′ N and 3°02′ S, and between 108°30′ and 114°10′ E. In this geographical location, the area of West Kalimantan is traversed by the equator (latitude 0°) precisely above the city of Pontianak, which is the capital of West Kalimantan. West Kalimantan is a tropical area with relatively high air temperature and humidity [14]. Supplementary Figure S1 shows a map of West Kalimantan, Indonesia. West Kalimantan has an area of about 147,000 km² [14], comprising 82,000 km² of forest (55.7%) and about 16,000 km² (10.8%) of peatland [15]. The percentage of residential areas in West Kalimantan is only 0.35% [14]. The distribution of the population in West Kalimantan is relatively uneven, and most of the settlements in rural areas are located on peatland areas.

The geographical factors of the scattered areas and different environmental ecosystems make it difficult for the government to provide and build the infrastructure needed by all the communities in the province of West Kalimantan. In areas that cannot be served by the government, such as rural areas, the independent role of the community needs to be optimally pursued. The role of this community includes the provision and development of infrastructure for the supply of clean water and proper sanitation. This can be performed if the community has adequate knowledge and skills. Communities who have the knowledge and skills can implement sustainable water management strategies without having to wait for facility support from the government. The effort to independently provide such services is referred to as the active role of the community in a participatory manner [16].

The province of West Kalimantan is crossed by the longest river in Indonesia, namely the Kapuas River, with a length of about 1143 km [17]. With the characteristics of the Kapuas River basin, and an area of approximately 100,000 km² [17], it should be sufficient to provide water for the surrounding community for the basic needs of living. Data published by BPS-Statistics regarding the West Kalimantan Province in 2021 show that the percentage of households with access to drinking water and basic sanitation services, by area of residence, in 2020 in the West Kalimantan province was only around 54.1% [14]. This value is still far below the average percentage of achievement at the national level. This value places the province of West Kalimantan as having the fourth lowest water security
index based on water facilities, and the fifth lowest based on socioeconomic factors, in Indonesia [18]. The rate of population distribution, used drinking water sources, and the proportion of households with proper drinking water and sanitation sources, by area of residence, in 2020 in the West Kalimantan province are shown in Table 1.

Table 1. Percentage distribution of population and household by regency or municipality, source of drinking water, improved sanitation and improved drinking water services, 2020 [14].

| Province/Regency/ Municipality | Population Distribution | Sources of Drinking Water | Improved Sanitation Services | Improved Drinking Water Services |
|-------------------------------|------------------------|--------------------------|-----------------------------|-------------------------------|
| Sambas                        | 11.6                   | 0.1                      | 4.0                         | 88.7                          | 0.3                          | 6.9                          | 87.6                          | 93.3                          |
| Bengkayang                    | 5.3                    | 6.5                      | 7.7                         | 23.1                          | 13.2                         | 49.5                         | 80.3                          | 59.3                          |
| Landak                        | 7.3                    | 9.2                      | 16.7                        | 21.4                          | 0.4                          | 52.4                         | 51.2                          | 45.6                          |
| Mempawah                      | 5.6                    | 1.0                      | 14.8                        | 73.1                          | -                            | 11.1                         | 82.2                          | 79.1                          |
| Sanggau                       | 9.0                    | 9.4                      | 29.9                        | 25.8                          | 6.1                          | 28.9                         | 70.1                          | 41.5                          |
| Ketapang                      | 10.5                   | 5.2                      | 24.4                        | 13.9                          | 1.3                          | 55.2                         | 82.5                          | 28.3                          |
| Sintang                       | 7.8                    | 25.8                     | 40.7                        | 4.5                           | 0.6                          | 28.4                         | 56.1                          | 19.5                          |
| Kapuas Hulu                    | 4.7                    | 6.7                      | 26.1                        | 21.1                          | 12.7                         | 33.3                         | 54.7                          | 50.8                          |
| Sekadau                       | 3.9                    | 29.3                     | 25.9                        | 18.2                          | 2.1                          | 24.6                         | 75.5                          | 31.1                          |
| Melawi                        | 4.2                    | 37.4                     | 26.5                        | 2.6                           | 3.8                          | 29.7                         | 68.0                          | 20.2                          |
| Kayong Utara                  | 2.3                    | 0.1                      | 8.4                         | 64.4                          | -                            | 27.0                         | 63.2                          | 80.9                          |
| Kubu Raya                     | 11.3                   | -                        | 13.4                        | 84.9                          | -                            | 1.7                          | 77.9                          | 85.1                          |
| Pontianak                     | 12.2                   | 0.4                      | 43.9                        | 54.9                          | 0.6                          | 0.2                          | 96.1                          | 55.4                          |
| Singkawang                    | 4.3                    | -                        | 31.1                        | 30.5                          | 16.5                         | 21.9                         | 88.4                          | 59.1                          |
| West Kalimantan province      | 100                    | 8.0                      | 24.1                        | 41.0                          | 3.2                          | 23.8                         | 75.8                          | 54.1                          |

The district directly adjacent to the location of the provincial capital of West Kalimantan is the Mempawah Regency. The site of Mempawah is in the lower reaches of the Kapuas River, and it is also a coastal area in the province of West Kalimantan. The percentage of households that have access to clean water sources and proper sanitation by place of residence (SDGs 6) in Mempawah, in 2020, was 79.1% [9]. On the basis of the location and characteristics of the land, this achievement is still low, considering the very high potential of water resources in Mempawah. This percentage shows that there are management problems that require attention in this district, so it is necessary to study clean water and proper sanitation in communities, especially rural communities, in the Mempawah Regency.

In achieving the SDGs, each region can set specific targets on the basis of priorities, regarding the economic, social, and environmental dimensions, according to the unique needs of each area [19]. The SDG 2020 action plan guidelines were prepared and carried out at the national level [20]. Under the target, the goal to be achieved is to create better human life in social and economic aspects, and to be able to synergize with the environment. The implementation of these SDGs cannot be ignored at the regional level, such as a district or city, or the national level. The role of the government is crucial in ensuring that the achievement of the SDGs is based on inclusive and participatory approaches, and strategies in socioeconomic development and environmental sustainability, while still prioritizing the characteristics and priorities of each region [21].

SDG implementation that adapts to regional characteristics can be carried out, such as in the study area in Mempawah which is dominated by peatlands that can be a provider of ecosystem services for local and national communities [22]. Peatlands have land characteristics that make them capable of storing rainwater. The water holding capacity of peatlands is indicated by the high percentage of water content. On land with a peat depth
of more than 20 cm, the rate of water content can reach a value of more than 300% [23,24]. The high number of water sources in peatlands could be an alternative source for meeting community needs [25]. With a high amount of water content, water sources in peatlands can be used sustainably and are very relevant to achieving the sixth SDG. An estimated 10% of the planet’s freshwater is stored on peatlands, making the health of these habitats critical for water security [25].

Although the amount of available water is relatively large, water from peatlands is naturally of low quality, below the standard for clean water for public health. Low water quality is based on color parameters, organic matter content, and water acidity. Peat soil is formed from plant remains that become organic matter. The high range of organic matter in peat water makes processing required before it’s able to be used as clean water [26]. Due to the low quality of peat water, it is difficult for people in rural areas to access clean water, especially during the dry season [27].

The survey results state that the use of surface water by the community is still minimal. The community in Mempawah only uses 1% of available surface water [9]. This is minimal when compared to the total wealth of surface water sources. It is necessary to find efforts and strategies to realize water security for the community by utilizing available water sources. In particular, rural communities living on peatlands need to formulate alternative management strategies to provide clean water and proper sanitation. Communities living on peatlands are pursued, considering that peatlands are a potential water source, to meet the need for clean water and achieve sustainable water security targets.

From the described problems, the purpose of this study is to formulate a management strategy for providing clean water and sanitation for rural communities. With this strategy, clean water and proper sanitation on sustainable peatlands can be provided for rural communities. Clean water is in line with efforts to achieve the sixth SDG.

2. Materials and Methods

Water security is generally defined as the ability of a community to maintain sustainability in meeting water needs, both in sufficient quantity, and quality that meet health requirements. This water security is essential to maintain the sustainability of life, human welfare, and socioeconomic development, to guarantee protection against water pollution and water related disasters, and to preserve natural ecosystems in a peaceful atmosphere and under stable political conditions [18,28–31]. The level of water security is expressed by the water security index.

The water security index in Indonesia is influenced by two main factors: water facilities and socioeconomic factors. Factors of water facilities include (1) aspects of community welfare, and (2) aspects of water pollution and water related disasters. Aspects of community welfare consist of proper sanitation, hand washing facilities with soap and water, proper housing, and net deforestation outside and inside forest areas. Socioeconomic factors include (1) aspects of meeting water needs and maintaining survival using a variable source of proper drinking water, (2) aspects of community welfare using the variable of own house ownership status, and (3) aspects of socioeconomic development. This uses the variable of gross regional domestic product (GRDP) per capita [18].

The water facility factor is able to explain water security by 50.39%. Meanwhile, socioeconomic factors are able to explain 28.03% of water security. The total cumulative percentage of the two factors is 78.42%, and the remaining 21.58% is the variance that cannot be explained by water facilities and socioeconomic factors [18]. The average household water security index (owned by the Province of Indonesia) is 58.20 [18].

The government’s efforts to develop a clean water infrastructure have only reached urban areas, such as provincial and district capitals. The difficulty in providing the equal distribution of services by the government to the entire community, apart from funding factors, is also caused by geographical factors, namely, the location of settlements scattered in village spots that are far apart from one another. In addition to funding and geographical factors, the human resource capacity factor is also limited.
Given the limited funds and human resources, it is necessary for the community itself to strive for the communal provision of clean water. This community’s independence refers to both providing materials and implementing development. Thus, the implementation method for providing clean water to rural communities should be carried out in a participatory manner.

In general, a participatory method implements an activity carried out by, with, and for the community itself. The participatory method can be used if the community has sufficient knowledge to utilize the natural resources around it. The participatory method approach is suitable for the implementation of integrated, comprehensive, and sustainable water resource management by considering the economic and social problems in the community [32,33].

Clean water and proper sanitation for urban communities can be provided by the government, but not for rural communities. This encourages rural communities to create access to clean water and proper sanitation for themselves. Through community participation, community empowerment is realized, encouraging communities to overcome social challenges and ensure sustainability in their own development [16].

This study was conducted using the case-study method, used to specifically explain the object under study as a case. This is expected to reveal the unique characteristics of water found in peatlands. The case-study method can be used to manufacture a product and test its effectiveness [34]. Results produced in a study constitute a strategy formulated based on conditions in the field. The field conditions analyzed are community problems and the potential of available water sources, in an effort to provide clean water and proper sanitation. Furthermore, an evaluation of the success of the strategy in meeting the needs of rural communities for clean water and proper sanitation for everyone is carried out, in accordance with the 6th goal of the SDGs.

The case studies under study reveal the unique characteristics of water found in peatlands. The characteristics studied are related to the quality of peat water, especially the parameters of organic matter content and the acidity of peat water. In order to maintain the availability of water in peatlands, it is necessary to control the water level elevation. The study was also conducted in the dry season, when the availability of water on the land surface was minimal.

This method is used to test the effectiveness of the strategy and its supporting infrastructure, peat water treatment installations, canal blocking, and drilled wells, in realizing water security on peatlands in the village of Wajok Hilir. The first stage was a survey at the study site and interviews with the people of Wajok Hilir to understand problems related to the peatlands in Wajok Hilir. On the basis of the obtained data, a strategy was designed to meet the needs of the rural communities for clean water. Furthermore, socialization was carried out regarding the maintenance of surface water sources. Peat water treatment and demonstrations were carried out for the public regarding peat water treatment plants, canal blocking, and drilled wells.

Applied test activities were also carried out to determine the effectiveness or influence of canal blocking and drilled wells in increasing surface water sources. The test activities and the efficacy of peat water treatment installations aimed to improve the quality of peat water in order to be suitable for use as clean water.

The participatory method was also used in this study. The people of Wajok Hilir were directly involved in planning, manufacturing, operating, and maintaining the peat water treatment plants, canal blocking, and drilling wells.

The study sites were selected on the basis of the following criteria: villages that (1) were peatlands, (2) were located close to the provincial capital of West Kalimantan but still had difficulties in accessing clean water and sanitation, and (3) were crossed by interdistrict traffic transportation so that they could be used as pilot villages.

With the specified criteria, the study location was Wajok Hilir village, located on peatlands. Wajok Hilir is in the Siantan district, Mempawah Regency, West Kalimantan province. Wajok Hilir is located on the border with Pontianak, the capital city of West Kalimantan.
Kalimantan. Wajok Hilir is about 11 km northwest of Pontianak. Wajok Hilir is the largest village in Siantan, with 53.3 km², or approximately 33.13%, of the area of Siantan. Wajok Hilir could provide surface water as an alternative source of clean water and proper sanitation for its people. Wajok Hilir is located at 0.0793° S, 109.3188° E; a map of Wajok Hilir is shown in Figure 1.

3. Results

3.1. Rainwater Potential in Kapuas Watersheds

Indonesia is located in a tropical climate zone with characteristics of high levels of rainfall in the rainy season and low levels of rainfall in the dry season. The characteristic tropical climate makes it challenging to control excess water in the rainy season and supply water during the dry season [36]. West Kalimantan, which is crossed by the equator, is a tropical area. The Kapuas River there, which is the longest river in Indonesia, is the primary source of water for the various needs of the people of West Kalimantan [37].

The Kapuas River spans about 1143 km, and stretches across nine districts and one city in the West Kalimantan province. The Kapuas River Basin has an area of about 100,000 km², or 68.4% of the total area of West Kalimantan province. The flow of water from the headwaters of the Kapuas River empties directly into the South China Sea. From upstream to downstream, the Kapuas River has varying widths. The width of the Kapuas River in the middle ranges from 400 to 700 m. Figures 2 and 3 show an overview of the conditions and situation in the Kapuas River.

![Study area in Wajok Hilir, West Kalimantan province, Indonesia](image1)

**Figure 1.** Study area in Wajok Hilir, West Kalimantan province, Indonesia [35].

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![Condition of Kapuas River](image2)

**Figure 2.** Condition of Kapuas River. (a) River morphology; (b) view across the river.
Water availability in the river is primarily determined by the amount of rainfall that occurs in the Kapuas watershed. Rain events in the rainy and dry seasons do not start and end in the same month every year. This results in uneven rainfall in the dry and rainy months. The analytical results show that the average annual rainfall for 45 years, namely, in 1968–2013, was 3206 mm; meanwhile, the average monthly rainfall is 267 mm [35]. Rainwater fills rivers and basin areas, such as lakes or swamps. The conditions of the lake in the upstream Kapuas River basin are shown in Figure 4.

Rainwater harvesting is ideal for countries with abundant rainfall, such as Indonesia [38]. A large percentage of the population in West Kalimantan, which is about 41% of households, using rainwater as a source of drinking water [14]. This percentage is far above that for water sources, such as rainwater and surface water (rivers, lakes, reservoirs, ponds, irrigation), by the Indonesian people in general, which is 3.5% [9]. Although rainfall is relatively high, rainwater utilization as a source of drinking water is still limited in Indonesia. Rainwater is only used as a source of drinking water by 2.4% of households in Indonesia [39]. For most families, this is because there are obstacles in the utilization of rainwater at the domestic level. The public perception is that the supply of water is limited in the dry season. Another obstacle is that people believe that rainwater quality is worse than that of other water sources [38]. In addition, many people believe that installing a rainwater harvesting system is expensive and, thereby, unaffordable [40].

Different conditions were found in the Mempawah Regency, where the percentage of people who harvested rainwater to meet their drinking water needs reached 73.13% [14].
This percentage shows that rainwater can be a water source for the community in Mempawah. In contrast, the use of surface water in Mempawah only reached 1% [14]. Surface water is of a quality that does not meet health standards, especially regarding color, acidity, and organic matter content from peat soil.

Data on average annual rainfall show that, during the rainy season, people in Mempawah can obtain clean water by harvesting rainwater. However, during the dry season, the people of Mempawah find it difficult to obtain clean water. Clean water sources in droughts are no exception for other communities in West Kalimantan, in particular, and Indonesia in general. Increasing water scarcity causes various types of pressure, such as on the agricultural and plantation sectors, and in meeting the daily needs of the community [41].

A strategy to provide sustainable water is needed that can always be used, in both the rainy and dry seasons. As Mempawah is dominated by peatlands, the water contained in rainwater storage peatlands should be reliable. Rainwater, however, is stored if the peatlands are still natural, so that their natural properties can be maintained. However, if there is a change in the characteristics of the peatlands in the dry season, there is drought on the peatlands, and this can even causes land drought, meaning that the land will burn more easily. For this reason, it is necessary to formulate a strategy to keep the water in peatlands from drying out during the dry season.

3.2. Groundwater Potential on Peatland Surface

Despite having sufficient natural resources, such as adequate rainfall and rivers, these resources cannot meet projected demand if there is no sustainable water management [42]. Due to water scarcity, policies that prioritize domestic water use over other water uses have been established globally by many national governments. Due to urbanization and population growth, a water supply system needs to be developed that is sustainable [43]. A water supply system that embraces sustainability can be established in two ways. First, this can be achieved by looking for alternative water sources, and using water resources more efficiently [44]. One of the alternative water sources in the study area that can be utilized is surface water on peatlands. Peatlands are natural water storage areas during the rainy season that can be used as flood controllers. However, in the dry season, peatlands release water, filling land that lacks moisture. Peatlands can then function as flood and drought controllers [45]. Peatland, throughout or for the majority of the year, is constantly dripping water or inundated (waterlogged) [46]. Peat is a type of saturated soil with water, that can store an amount of water between 1 and 13 times its weight [47]. Peatlands in Wajok Hilir are affected by average rainfall and sea level tides, so that the water needs of the people of Wajok Hilir can be met throughout the year [48]. The average rainfall in Wajok Hilir in 2010–2019 was in the range of 127.6–273.5 mm/month, while the water level in Wajok Hilir ranging from 50 to 100 cm [49].

The people in Wajok Hilir mostly use surface water in the canal. Water in the channel is brownish, has a high acidity level, and an organic matter content that is three times above the required threshold. Figure 5 shows an illustration of water in tertiary canals in the peatlands. The quality of peat water is deficient if it is not first treated. The content of organic matter (KMnO₄) in peatlands is around 450 mg/L. The amount of organic matter content is high, making it necessary for it to be processed before use. The results of laboratory tests of peat water, before and after processing, are shown in Table 2.

Based on the potential for rainwater and surface water on peatlands, it is known that rural communities on peatlands should be able to meet their needs for clean water and proper sanitation for their lives. However, because there is no clean water supply system served by the government, rural communities use naturally available water around their settlements.
daily needs such as washing and bathing; (Figure 5. Tertiary canal in Wajok Hilir. (a) Water in tertiary canal used by the community to meet daily needs such as washing and bathing; (b) red–brown peat water.

Table 2. Efficiency of peat water treatment equipment based on laboratory test results [50].

| Parameter | Unit | Quality Standards (Maximal Level) | Value Before | Value After | Efficiency |
|-----------|------|----------------------------------|--------------|------------|------------|
| pH        | mg/L | 6.5–8.5                          | 5.87         | 7.87       | 34.07%     |
| DO        | -    |                                  | 5.08         | 8.30       | 63.38%     |
| TSS       | -    |                                  | 9            | 8          | 11.11%     |
| Color     | TCU  | 50                               | 1160         | 33         | 97.15%     |
| BOD       | -    |                                  | 12.91        | 2.4        | 81.40%     |
| Iron (Fe) | mg/L | 1                                | 2.84         | 0.02       | 99.29%     |
| TOD       |      |                                  | 104.3        | 19.27      | 81.52%     |

| Temperature °C | Air Temperature ± 3 | Value Before | Value After | Efficiency |
|----------------|---------------------|--------------|------------|------------|
| 26.3 °C        | 26.1 °C             | 104.3        | 19.27      | 81.52%     |

4. Discussion

The field review and implementation results show that the availability of water in peatlands is great. The amount of available water differs in the rainy and dry seasons. In the rainy season, surface water floods the land; in the dry season, the land experiences drought, which causes the water level to be far below the ground surface. With the difference in the amount of available water in the rainy and dry seasons, sustainable water management efforts are necessary.

Peat water is of low quality and does not meet clean water requirements according to public health standards. To provide clean water sourced from peat water, it is necessary to first treat it. Currently, there are no efforts by the government to treat peat water. To meet the need for clean water, the community relies on rainwater that they store during the rainy season. When it does not rain, people who do not have adequate rainwater storage areas find it difficult to access clean water.

Clean water can be accessed if rural communities have adequate knowledge and skills in the utilization of peat water available around them. Efforts to provide infrastructure for peat water treatment and management can be provided by the community in a participatory manner, so that water security for rural communities can be realized. To realize water security, a strategy is needed for managing peat water resources, and measures to provide clean water and proper sanitation are needed for rural communities on peatlands.

4.1. Strategy for Managing Surface Water Resources on Peatlands

Due to population growth and increasing water demand, water management is urgently needed [51]. Regarding the potential for rainwater and surface water on peatlands, West Kalimantan does not suffer from water problems in terms of quantity. SDG 6 can be
achieved by 2030 if the existing potential can be utilized. The utilization of water sources is based on quantity, and quality must meet health standards. Therefore, for the sixth SDG, subsequent efforts must be made.

By considering geographical factors (remote settlement locations), then, the sixth SDG in peatland rural communities can be achieved with the right strategy, that is, a self-service strategy in the form of community empowerment in fulfilling their own needs. Provision of clean water will be easier, cheaper, and environmentally friendly if this strategy is carried out communally (one clean water treatment plant serving about six to eight houses).

In order to realize water security to meet the needs of clean water and proper sanitation for peatland rural communities, it is necessary to ensure the availability of sufficient water in both the rainy and dry seasons. Clean water services in a sustainable manner can be carried out if the availability of water in peatlands can be relied on. In other words, in order to increase the water supply, it is necessary to control the groundwater level. The low quality aspect of peat water can be improved by processing it before it is used by the community. To be able to play a good and active role, people need to increase their knowledge. The implementation of a self-service strategy to meet the needs for clean water can be carried out by empowering the community to build infrastructure for the provision and treatment of clean water in a communal manner. The infrastructure needed is infrastructure for controlling groundwater levels and peat water treatment.

4.1.1. Controlling Groundwater Level

The groundwater level continuing to decline can result in a decrease in the function of peatlands in absorbing and storing water, so the peatlands could experience irreversible drying conditions [52]. Peatland groundwater could become as surface water.

The groundwater level of peatlands can be increased by controlling drainage, so that the water that comes out of the land to wash the ground is not excessive. Drainage control to maintain the water level can be carried out by constructing canal blocking infrastructure in the channel. The surface water level of peatlands can be raised to more than 25 cm by canal blocking infrastructure [35]. Table 3 shows a comparison of the water level in canals or land equipped with canal blocking buildings. The community, in a participatory manner, can develop canal blocking.

Table 3. Average water levels in observation area [35].

| Item       | Observation Area Location |
|------------|---------------------------|
|            | 1  | 2  | 3  | 4  |
| Max (cm)   | 73.3 | 69.5 | 79.5 | 77.8 |
| Min (cm)   | 45.5 | 14.5 | 45  | 22.5 |
| Interval (cm) | 27.8 | 55.0 | 34.5 | 55.3 |

Note: 1 = land around quaternary canal where a canal block has been built; 2 = land around quaternary canal where a canal block has not been built; 3 = tertiary canal where a canal block has not been built; 4 = land around tertiary canal where a canal block has not been built.

The community can independently build canal blocks if they have sufficient knowledge to do so. In general, the community does not know how to create simple canal blocks, so socialization is needed to provide the relevant knowledge and skills. In addition to socialization via teaching, it is also necessary to offer training and practice sessions in the field, for the village community; in addition to gaining knowledge, they can also apply this strategy to the area around the community’s settlements.

By constructing canal blocks, lowering of the surface water level on peatlands can be maintained. The construction of canal blocks can also be used to collect water in the canal, as a water reservoir in the channel that functions as water storage to meet the water needs in rural areas. Controlling the water level in peatlands with block canals built over tertiary and quaternary channels for all peatland locations is recommended. The construction...
of canal blocks reduces the volume of water that comes out of peatlands, to increase the soil water content of peatlands. Canal blocking blocks the flow of water from peatlands that can easily escape through channels, so that water is trapped and seeps into the peatlands around the canal blocks [35].

With the high water table on the surface, the amount of available surface water is significant on peatlands. The amount of usable water shows that groundwater on the surface of peatlands could be a source of clean water for rural communities, evidenced by the conditions in Wajok Hilir, in which clean water can be provided by independently treating peat water.

The materials needed to build simple canal blocks can be quickly and cheaply obtained by the community. A photo of a simple canal block in the field can be seen in Figure 6. After having been built for about three years, the canal block is expected to grow ferns, which are typical plants found on peatlands. With the growth of this plant, water blocking in the canal can occur in order to restrain the rate of water release from the peatland, so that the water level in the peatland can be naturally maintained at no more than 40 cm from the soil surface. By controlling the water level, the moisture and presence of water in peat soil can be maintained.

On a global scale, peatlands offer various ecosystem services, such as being a source of clean water [52]. The availability of water around community settlements comes from groundwater on the surface of peatlands. Communities directly use surface water on peatlands without treatment for needs such as bathing, washing, and restrooms. The condition of peat water can be seen in Figure 5. The fulfillment of water needs in quantity is not followed by improving its quality [50].

The results of processing and testing peat water samples, carried out at the Environmental Chemistry Laboratory, Faculty of Engineering and the Laboratory of Land Quality and Health, Faculty of Agriculture, Tanjungpura University, showed that there was an increase in the pH parameter from acidic to neutral (pH around 7) by 34.0.07%, a decrease in color parameters of 97.15%, iron of 99.29%, and a decrease in organic matter of 81.52% [50]. All parameter values met the criteria for clean water based on Class II, according to PP RI no. 82 of 2001 [53].

Peat water is characterized by a brownish–red water color caused by dissolved organic matter content from the weathering of plant residues. Its density indicates the quality of the water. Another characteristic is the high level of acidity resulting from plant decomposition [54]. Peat water has a low pH (3–5), is brownish–red in color, and contains many organic substances, so it does not meet the requirements of household or raw water for drinking [53,55].

If not treated in its use as a water source, peat water can cause health problems for humans [56]. The characteristics of peat water are not suitable for health. Peat water causes tooth decay and abdominal pain due to its low pH. Besides its odor, due to the high content of organic substances, peat water can be biodegraded and carcinogenic when used with

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**Figure 6.** Canal blocks in the field. (a) Participatory construction of canal blocks by the community [35]; (b) canal blocks on peatland after approximately 3 years of being overgrown with plants enabling a natural canal blocking function.

4.1.2. Processing of Peat Water Sources

On a global scale, peatlands offer various ecosystem services, such as being a source of clean water [52]. The availability of water around community settlements comes from groundwater on the surface of peatlands. Communities directly use surface water on peatlands without treatment for needs such as bathing, washing, and restrooms. The condition of peat water can be seen in Figure 5. The fulfillment of water needs in quantity is not followed by improving its quality [50].

The results of processing and testing peat water samples, carried out at the Environmental Chemistry Laboratory, Faculty of Engineering and the Laboratory of Land Quality and Health, Faculty of Agriculture, Tanjungpura University, showed that there was an increase in the pH parameter from acidic to neutral (pH around 7) by 34.0.07%, a decrease in color parameters of 97.15%, iron of 99.29%, and a decrease in organic matter of 81.52% [50]. All parameter values met the criteria for clean water based on Class II, according to PP RI no. 82 of 2001 [53].

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If not treated in its use as a water source, peat water can cause health problems for bodily organs if it is continuously consumed, due to its high metal content [57].

Before processing, a preparatory stage for peat water treatment is carried out. Preparation begins with taking samples of peat surface water, which is the source of raw water to be processed into clean water for parameter quality testing. The water used by the Wajok Hilir community is of low quality, as the results of testing several peat water parameters show, namely (1) color: the peat water is red to brown with a value above 1000 TCU; (2) acidity level: the pH of the peat water is less than 6; (3) iron: the iron content is more than 2 mg/L; and (4) organic matter (KMnO4): the organic matter content is more than 400 mg/L. The peat water treatment plant is shown in Figure 7.

![Peat water treatment plant](image)

**Figure 7.** Peat water treatment plant. (a) Installation around people’s houses that can communally serve about six to eight houses; (b) installation in places of worship.

Alternative surface water treatment on peatlands needs to be established to fulfill the need for clean water and proper and sustainable sanitation for everyone, especially rural communities on peatlands, to achieve the sixth SDG. The community can treat peat water to produce clean water if they have the knowledge and skills in water treatment. In general, people use surface peat water for their daily needs directly, without processing it.

Peat water samples were processed and tested at the Environmental Chemistry Laboratory, Faculty of Engineering and the Laboratory of Land Quality and Health, Faculty of Agriculture, Tanjungpura University. Peat water samples showed an improvement in water quality, namely an increase in pH parameters from acidic to neutral (pH 7), a processing efficiency of 35%, and a decrease in the value of the color parameter, reaching 30 TCU. Processing is 97% efficient. Treated water exhibited an iron parameter of less than 0.1 mg/L, or a processing efficiency of 99%, and a decrease in organic matter content with a value of less than 20 mg/L, or processing efficiency of 81.52%. Thus, all water quality parameter values met the criteria for clean water based on Class II according to PP RI no. 82 of 2001 [53].

After testing the parameters and obtaining laboratory results, the activity phase begins with community socialization. Socialization provides knowledge and skills to the community for processing peat water into clean water [48]. The community is exposed to the potential use of peat water as a raw water source in rural peatlands, the peat water treatment method that is applied, and the introduction of coagulant materials commonly used to treat peat water.

The socialization was carried out via teaching, and then continued with training and field practice to construct peat water treatment plants with simple technology. The community could independently build a simple peat water treatment plant using coagulation and sedimentation methods. The coagulants used are also cheap and easy to source for the public, such as alum, PAC, and lime. After the coagulation process, the water is left for a while so that the sedimentation process can occur. The results of processing peat water into clean water are shown in Figure 8.

Then, by continuing to assist the community, the quality of the treated peat water was tested to determine whether it met the requirements for clean water, so that the community could independently process peat water into clean water by installing peat water treatment...
with a simple technology, used communally by the community, to meet their daily clean water needs.

![Peat Water, Bottled Water, Peat Water After Processing](image)

**Figure 8.** Comparison of the color of peat water, bottled water, and peat water after processing.

### 4.1.3. Knowledge and Skills in Well Construction

The problem in rural areas on peatlands during the dry season is the lack of water sources; even for wetting peatlands, water sources are challenging to find. Efforts by the community to meet water needs and wetting peatlands during the dry season involved build their boreholes, but there was a failure due to gas escaping from the ground. The people never dared to try it again. The wells that were remade were closed by the community [45].

The construction of drilled wells aims to overcome the scarcity of surface water sources during the dry season. On peatlands, in addition to meeting the community’s need for clean water, drilled wells also function for peat wetting, especially during the dry season. The available water in drilled wells can be relied on in wet peatlands as a source of water when there is no rain [45]. There are certain location criteria that are required for the construction of drilled wells, and techniques for selecting the type and design of simple boreholes. In general, boreholes consist of a suction pipe and a casing pipe. Drilled wells are constructed to reach the free aquifer. The depth of the aquifer is not the same in different locations. Using a casing pipe, the solid material in the aquifer does not come out of the well [58].

A failure of bore well construction by rural communities can be caused by a lack of knowledge and understanding. Effort was made to provide socialization with lectures to provide and improve the knowledge and experience of the community with regard to peatland wetting. The presented material was in accordance with the characteristics and typology of peatlands, quality, and management methods [45].

The knowledge that is useful for keeping peat wet and its advantages also needs to be conveyed to the community. The general public can be affected by peatland droughts. Socialization is also directly offered by practicing or demonstrating how the community can independently produce boreholes, and play an active role and directly apply this strategy to the area around its settlements.

In addition to completing the borehole construction process, it is also necessary to test the wells to find water from the aquifer, assembling tools with the community. Water from bore wells can be a source of raw water for rural communities, but it is necessary to evaluate and test its quality because the peat soil quality influences the quality of water obtained from drilled wells.

### 4.2. Implementation of Self-Service Strategy in Rural Areas on Peatland

The formulated strategy needs to be complemented by real efforts in the midst of the community with a work process. Community empowerment efforts in the implementation of the self-service strategy in providing clean water and proper sanitation in rural areas on peatlands are carried out in the following way.
4.2.1. Socialization

Socialization provides knowledge about the management of clean water and proper sanitation to rural communities, and could be supplied by universities, relevant government agencies, and stakeholders in the form of corporate social responsibility (CSR).

In clean water management, the initial involvement of stakeholders, such as government agencies, is emphasized as a significant success factor in implementing the strategy. Education of and outreach to the community are essential for raising public awareness. Therefore, education can be a solution to clean water and sanitation problems faced by the community, provide information, and promote a general understanding about water management and its role as a reliable source of clean water to maintain water security [59]. Socialization activities are shown in Figure 9.

![Figure 9. Socialization activities in the village community.](image)

4.2.2. Pilot Project

An infrastructure building was constructed as a pilot project to improve the community’s ability to manage clean water and proper sanitation. Documentation of the infrastructure buildings constructed as part of the pilot project can be seen in Figure 10.

![Figure 10. Infrastructure buildings built as part of pilot project. (a) Well drilling infrastructure; (b) peat water treatment installation infrastructure.](image)

4.2.3. Operational

The community also needed to be directed on how to operate the pilot infrastructure that had been built because good operational capabilities are required to maximize its performance. Documentation of the tutorial delivery activities can be seen in Figure 11.

![Figure 11. Documentation of the activity of delivering the operation tutorial to the community.](image)
4.2.4. Accompaniment

During the socialization process for infrastructure operation, the community was temporarily assisted, so that infrastructure development and operations could run effectively.

4.2.5. Material Supply

Materials were provided to partners, so that the existing pilot infrastructure in rural areas could be more widely spread, and they could become pioneers in the management of clean water and proper sanitation for other villages. This would raise more widespread awareness of the importance of clean water and adequate sanitation, and the sixth SDG could be achieved for all levels of society.

With the management and provision strategy implemented, water security for rural communities can be achieved. This is indicated by the community's ability to maintain sustainability by meeting the needs for clean water and sanitation in terms of quantity and quality. The formulated strategies and steps can be independently implemented, and sustainably, in a participatory manner. This participatory method greatly assists the government in accelerating the achievement of providing clean water and sanitation for communities to support the SDGs.

The water level control strategy protects the environment, especially the peatland ecosystem. Low rainfall intensity in the dry season can cause dryness in peatlands. Peat has unique characteristics in absorbing and storing water. Long term droughts can cause peat soil to reach a state of irreversible drying. Irreversible drying conditions reduce the ability of peat soil to absorb and store water during the rainy season. In order for peat to not reach irreversible drying conditions, water must be maintained at a certain level. The controlled water level can reduce the damage to peat characteristics due to the impact of land droughts, while also reducing the risk of flooding due to reduced absorption and storage capacity.

5. Conclusions

The availability of rainwater as a source of clean water in West Kalimantan has great potential. The rain that occurs is stored in rivers, lakes, and peatlands. The characteristics of peatlands need to be managed and maintained for them to be used as rainwater storage facilities. To realize water security in rural areas, a self-service strategy needs to be implemented that is formed from community empowerment in fulfilling their own needs. The provision of clean water will be easier, cheaper, and environmentally friendly if this strategy is carried out by empowering the community to build infrastructure for communal water supply and treatment. The infrastructure needed is infrastructure for controlling groundwater levels and peat water treatment.

Community empowerment efforts for the implementation of self-service strategies in the provision and treatment of clean water for the community peatland villages include (1) socialization carried out in an integrated manner; (2) infrastructure development as a pilot project; (3) providing knowledge about infrastructure operations; (4) providing temporary assistance to the community; and (5) providing material supplies, so that rural communities who are partners can become pioneers in disseminating clean water management for water security in other rural areas. This formulated strategy can improve the ability of rural communities to realize water security and support achieving the SDGs.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/w13182455/s1. Figure S1: Map of West Kalimantan, Indonesia.

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