Article

Red, White, Rain, and Packaged Water: Adaptive Strategies to Clean Water Scarcity in Kepulauan Meranti's Outermost Islands, Indonesia

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Abstract
Peat communities in Kepulauan Meranti face clean water scarcity and the lack of a national clean water supply system. We aim to observe local adaptation strategies in response to locally available water resources. We examined two villages (Lukun and Beting) and a city (Kota Selat Panjang), and ethnicities (indigenous Orang Akit, Malay, and Tionghoa) and problems concerning clean water scarcity. We conducted participatory observations and in-depth interviews for two months. We gathered data on water sources, perceptions regarding causes of water scarcity, and adaptation strategies. There are four local water sources. They are peat water (red water), borewell water (white water), rainwater, and packaged water. The perceived quality of these sources is influenced by environmental, religious, cultural, and economic values, affecting each ethnic group's adaptation strategies. Rainwater is perceived as a clean source accessible to all, but differs in practices to access depending on economic condition. Peat water or rhedang water is perceived differently among the ethnic groups; Orang Akit relies on peat water and perceives it as freely available clean water. The Orang Akit demonstrated notable adaptability to peat water, but they are the most vulnerable community due to limited livelihood. The other two ethnic groups have more access to rainwater and perceive peat water as clean as rainwater. Adaptation to water scarcity in peatland differs in ethnic groups depending on their values and livelihoods.

Keywords
adaptation strategies; ethnicity; peatland communities; water resources; water scarcity

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INTRODUCTION

Water is a main resource for living (Aldaya et al., 2021; Patrick et al., 2019), but is environmentally threatened. Water is demanded for primary needs and secondary needs, supporting economic and social activities (Sabale et al., 2023). Some sectors demand water, for instance, transportation, agriculture, fisheries, and recreation (Falkenmark, 2020; Falkenmark et al., 2019). Worldwide, environmental degradation threatens water resources (decreases the availability of clean water and pollutes water resources) (Dai et al., 2023; Dettori et al., 2019). In 2015, global inhabitants were lack of access to potable water (29%), and lacked safe sanitation (61%) (Adeloju et al., 2021; Humphrey et al., 2019; Prüss-Ustün et al., 2019; Sutapa et al., 2020). Clean water scarcity has an impact on 40% of the global population (Rao & Mamatha, 2004; Srikanth, 2009; Zhou, 2020). Therefore, the sixth goal of the Sustainable Development Goal (SDG 6) is to ensure the availability of clean and potable (drinkable) water and sustainable sanitation (Herawati et al., 2021; Schipper et al., 2021; Schroeder et al., 2019; Thapa, 2023).

Similarly, Indonesia, the largest water user in Southeast Asia, is facing potable water scarcity, particularly in the peat ecosystem in its outermost islands. Water in peat ecosystems supports communities in the areas and critically functions to sustain the peat ecosystem ecologically (Astiani et al., 2018; Bertrand et al., 2021; Salimi & Scholz, 2021; Tata, 2019). The peat island ecosystems are limited in access to clean water due to the unavailable national clean water system and decreasing local water availability. Environmental changes (forest degradation and peat fires) decrease water quantity and quality (Febria et al., 2021; Mawarni et al., 2020). We observed peat communities' adaptation to clean water scarcity in the outermost peat islands in Indonesia. The rationale is that our preliminary observation assured that the islands are prone to peat degradation. Since 2014, peat water flowing to a village has decreased and causing villagers to adapt to limited water availability for their daily needs.

This study is located in two outermost small peat islands in Kepulauan Meranti Regency, Riau Province, Indonesia. These two islands are vulnerable in terms of peat degradation threatening peatland sustainability in the areas; hence, the size of the areas is decreasing due to robbing/soil erosion (Sutikno et al., 2017). Studies have rigorously discussed the physical aspect of sustainability in the peat island ecosystems. For instance, the peat restoration agency has focused on disaster mitigation since 2016 through rewetting, revegetation, and revitalisation economic aspect. Although local communities were made involved in projects, the true sense of the social aspect is missing. Therefore, our study adds a human dimension to peat studies related to natural resources.

METHOD

Study Areas

Administratively, we studied three villages in Kepulauan Meranti District, Riau Province, Indonesia. In terms of peat ecosystems, the three villages are located in the PHU Tebing Tinggi and Pulau Rangsang. Prior to this study (in May-July 2022), we observed the existence of ethnicity in the three locations. In PHU Tebing Tinggi, Lukun village represents Malay ethnicity and Selatpanjang represents a mixture of ethnicity (Tionghoa, Javanese, and Orang Akit) (number 1, Figure 1). In PHU Pulau Rangsang, Beting village, representing the indigenous people of Orang Akit. Lukun and Beting are villages located in peatlands. Selat Panjang is a peat city located along the coast of the Air Hitam Strait in Riau Province, distributed in peatlands and non-peat areas (number 3, Figure 1).

The three locations may differ in the sources of problems related to clean water scarcity due to lanscape, environmental degradation and livelihood. Beting village is located front part of Pulau Rangsang facing Pulau Tebing Tinggi, and it is surrounded by rivers (number 2, Figure 1).

Collecting Data

This study is a descriptive qualitative

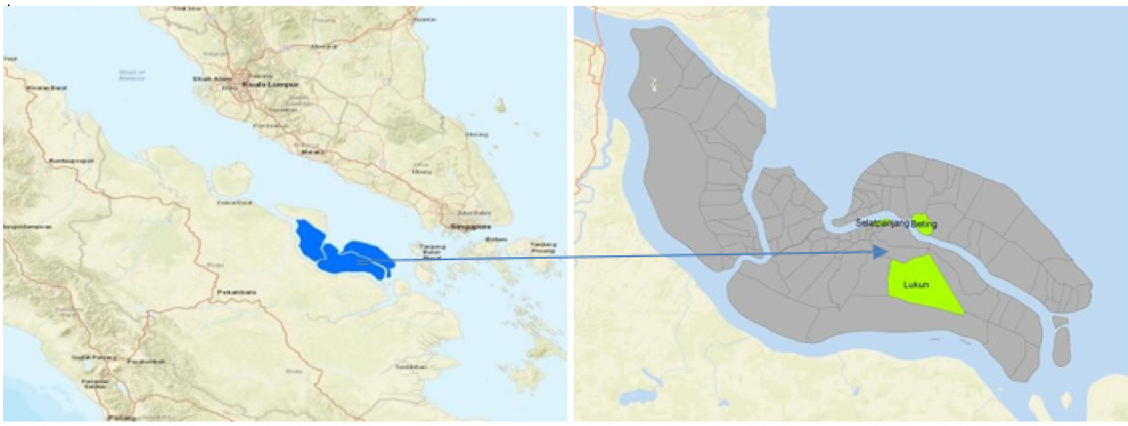

Figure 1. Areas of studies in Pulau Tebing Tinggi and Pulau Rangsang (left), the locuses are indicated (right): (1) Lukun Village, (2) Beting Village, (3) Kota Selat Panjang. Source: Author's work

study. Data were collected from May to July 2024 through in-depth interviews and participatory observation. The source of data is: (i) 10 specific informants who understand the landscape of peatlands in their areas and their changes, water resources, utilization of water, and connection to gather a more complete explanation; and (ii) 18 general informants who are not required to have specific information. Determining the specific informants initiates the research step and then followed by in-depth interviews. The result of these interviews became the basis for determining general informants for further interviews and observation, and participatory observation. General informants were chosen from different generations (ages), genders, livelihoods, and education. Unstructured interviews were carried out through open questions and aimed to explore the uses of water by people living in the three locations, their traditional knowledge about water uses, strategies, and adaptation in choosing water sources. The interviews were set as casual conversation and a telling story, recorded and noted in a fieldwork note. The recording and notes were transliterated, reduced, and compiled. The data were analysed by narrative description.

RESULTS AND DISCUSSION

In the global context, water scarcity is a threat to global societies economically and to human well-being. Clean water scarcity is related to water quality and water availability. In terms of water quality, economic activities are associated with polluting natural resources. Naturally free water has become costly (not affordable to the marginalised population) (Chakkaravarthy & Balakrishnan, 2019). Approximately 40% of the global population (2.2 billion people) lack access to safe drinking water. Certain situations have worsened the situation, for instance, in the corona pandemic (50% of the global population is living in waste-stressed areas). Waterborne diseases spread and threatened the global population (Mishra & Tushaus, 2022).

In the context of the peat ecosystem, peat material stores water to help it function. However, water stored in peatlands might be threatened by climate change and drainage, leading to a decrease in water. In the global peatland context, for instance in Canada, there is a decrease in water yield from the peat ecosystem due to water table fluctuation (Bourgault et al., 2017). In Indonesia, peat ecosystems perform peat hydrological units (PHU) where peatlands are located between two rivers, or bordered by a sea, or in swamp areas. They provide water to communities as one of the peat ecosystem services. Peat ecosystems store and regulate water in this ecosystem, such as flood attenuation, baseflow contribution to rivers, and maintaining groundwater levels in surficial aquifers. Rigorous studies examined water tables, showing that vast areas of peatlands are drained, decreasing water storage.

In Indonesia, peat water is not suitable for local clean water resources based on the national standard. Peat water is acidic (pH of 3-5), high in organic matter content, red-brown colour, high suspended sediment concentration, and high concentrations of Fe metal and dissolved organic carbon (PKEG, 2022). Technologies to purify peat water have been developed, including a technological innovation in Indonesia, namely IPAG60, electrocoagulation systems, and plasma ozone technology (Ali et al., 2021). Although IPAG60 is recommended as a cost-effective measure, the large- scale implementation has not yet been found in Indonesia. Some pilot peat water treatment areas were developed in Riau, but the enlargement of the pilot areas has not been observed.

Human Adaptations to Peat Environmental Conditions

Human are an adaptable species to environmental conditions, supporting their existence to date. Human beings are proven to adapt in extreem conditions like in (i) life in the arctic by Siberian peoples such as the Chukchi and the Evenks, Europeans such as the Sami, and Native North Americans, most famously the Inui, (ii) high-altitude adaptation by Amhara in Ethiopia, the Quechua and Aymara in the Andes, and Tibetans and other people in and around the Himalayas and the Tibetan plateau; and (iii) adaptation to diving by the Sea Nomads of Southeast Asia. The adaptation involves biological adaptations, in addition to technological innovations, that have enabled these geographical and cultural explorations (Ilardo & Nielsen, 2018; Jeong & Di Rienzo, 2014).

Ever since, people living in peatlands in Indonesia have adapted to the waterlogged ecosystem. As a water source, rivers in peatlands have become a major civilised areas of peat ecosystems for trading. The science of peatlands emerged in Indonesia in the 1970s, about more than a century after the trading in rivers of peat ecosystem. For instance, studies of Polak (1975) and Driessen (1978); thus, the understanding of inhabitants about the types of land they occupied is missing (Page et al., 2006). In Sumatra, particularly in Riau Province, people living in peatlands can be reviewed from river trading and the development of plantations after 1870 (after the development of plantations in hilly areas of Indragiri, Riau). A steady increase in forestry and agricultural products followed the Dutch intervention and decreased Siak Sultanate influences. River trading increased with the development of Penang and Singapore, and the Suez Canal, as well as the trading was unaffected by World War II (Mizuno et al., 2016). To this point, it is assumed that clean water in peatland was not an issue discussed in the peatland human knowledge dimension, or that people are adaptable to peat water.

Water and Economic Capability

Water is a fundamental need of human beings, significantly impacting growth and economic development. This importance is understood from the relation of population growth and water use in the last century (Duarte et al., 2014). The interaction between economic processes and the uses of water involves some factors affected by food choices, climate change, the reformation of policies, and technological development (Zahedi et al., 2024). In China, economic growth and social development as a cause of conflict related to water resources; hence requires strategies for sustainable development (Jia et al., 2018).

A negative relationship between economic growth and water use is modelled. It is elicited that although maximum uses of water increase productivity, overuse of water restricts growth. Besides, increasing trade intensity and national income increase the water consumption pattern. This indicates that there is a necessity to bring intervention through policies of effective water management (Hoehn & Adanu, 2008). Sustainable water resource management is a measure to mitigate climate change, overexploitation, pollution, threatening social-economic welfare, and the environment (Argente García et al., 2024).

Values of People Living in the Peatland to Water

People living in peatland are locals and migrants, and they differ in values towards water. The local communities have a strong relationship with the peat landscape, while migrants use peatland as an instrument in economic utilisation (Abdurrahim et al., 2023). Locals realize significant economic benefits of peat in the form of ecological services as flood control and climate regulation (Syahza et al., 2019; Yunus et al., 2024). Local communities are also closely linked to identity values, traditions, and spiritual beliefs, and to the importance of caring for peat as a legacy of knowledge passed down from their ancestors. These values and knowledge then become community support for peatland conservation and restoration policies (Heindorf et al., 2024; Schulz et al., 2019).

Peatland restoration values water to sustain peatlands by attempting to improve ecosystem services for local communities requires a holistic approach. Considering local values, government support in developing local people's livelihood choices, it is hoped that they can achieve economic and social targets based on the values of local communities (Elia & Yulianti, 2022; Farrell et al., 2024). Peat management practices for agriculture and plantations are also carried out in an environmentally friendly manner through the Peat Care Independent Village (*Desa Mandiri Peduli Gambut*), which has the goal of controlling the degradation of peat ecosystems through community participation, such as in Central Kalimantan, Indonesia (Irwani et al., 2022).

Source of Water and Utilisation in the Three Vilages of Small Peat Island

This study identified four sources of water utilized for domestic purposes by residents in Lukun Village, Beting Village, and Selat Panjang. These water sources include peat water (locally named redhang water in Lukun and red water in Beting and Selat Panjang), rainwater, borewell water (known as white water in Lukun and Selat Panjang), and packaged water. Table 1 provides a detailed description of the uses of these four water sources across the three study areas.

In Lukun and Beting, clean water scarcity is related to the unavailability of water other than peat water. In Selatpanjang, clean water scarcity is caused by saltwater intrusion into the bore wells. The only com-

Table 1. Uses of peat water, rainwater, borewell water, and packaged water in the Lukun, Beting, and Selat Panjang, Kepulauan Meranti, Riau Province

Villages	Peat Water (Redhang or Red Water)	Rainwater	Borewell Water (White Water)	Packaged Water
Lukun	Locally named *Redhang*, intensively used for drinking and domestic purposes for 20 years (before environmental changes). After availability decreased, used mainly for bathing and cleaning.	Intensively used after environmental changes reduced *Redhang* quality; stored in tanks.	Salty and stinky; unsuitable for drinking; unaffordable for citizens.	Limited use, especially for guests from Pekanbaru (cities).
Beting	Locally called *Air Merah* (red water), tea-like, used directly for drinking and cooking, perceived as healthy.	Limited rainwater collected; people use it wisely for drinking and cooking.	None	None
Selat Panjang	Locally named *Air Merah*; mainly used for laundry and bathing; unsuitable for consumption due to pollutants and brackish mixing.	Main source for consumption and cleaning; stored in large tanks or cemented ponds.	Unsuitable due to brackish content.	Increasingly popular since 2010 for drinking water.

mon water source accessed in the three locations is rainwater. Orang Akit in Beting village mainly work to produce charcoal from mangrove trees and as fishermen. Their access is limited to a small boat called a pompong to Selat Panjang, and motorcycles and canoes for local transportation; thus, limiting their access to other sources of water. People living in Lukun work in the Sago Plantation and log the forest, as the village is near forest areas. Similar transportation in Beting was found in Lukun, but more boats. People living in Kota Selat Panjang have a variety of livelihoods and have more access to modern living due to their access to local, national, and international harbours.

Uses of Water Resources in Lukun Village And Adaptation to Peat Degradation

Uses of Air Redhang in Lukun, From Cleaning to Cooking

In Lukun, people name peat water as *Air Redhang*, pure water of the peat ecosystem. People in Kepulauan Meranti, outside Lukun, call it peat water. *Redhang* means red or brownish red or redish brown. It is also called the thousand- rooted water. People in Lukun perceive that *Redhang* is located far, deep, pure, and refreshing to drink, unlike borewell water and packaged water. Amran from Lukun perceives that *Redhang* originates from tree roots growing in a pristine peat ecosystem. This perception is associated with the geographical location of Lukun near the peat forest areas with dense trees and deep peat (> 3 m depth). Lukun is particularly located in the middle of Pulau Tebing Tinggi, where peat domes are located and store a large amount of water in their pristine state; but canals flow the water to the village (Figure 2).

People in Lukun dominantly use *redhang* to drink, bathe, and clean, and inherit the habits from their predecessors. Particularly for drinking water, people identify drinkable *redhang* as clear, reddish, slightly brown, and not contaminated by waste (domestic waste), pollution, or other chemical contaminants. Researchers confirmed in the field that farmers or people in Lukun consumed *redhang* during their work. For instance, 3 labourers of sago tree cutting brought *redhang* in 600 ml bottles to consume during their work (Figure 3), and they perceive that the redhang is accessible water in the sago plantations, fresh and healthy water, even without cooking the water. The values have become their belief. The availability of *redhang* makes this source affordable, practical, and natural.

Figure 2. Rhedang water flowing through a canal in Lukun Village

Figure 3. Redhang water packaged in a bottle by a sago labourer

Perceived Decreasing Quality And Quantity of Redhang Water Due to Environmental Changes And Adaptation of People in Lukun

Table 2 summarizes the perceived quality and quantity of redhang water in Lukun. *Redhang* water is abundant in a pristine peat ecosystem, but it is perceived that environmental changes have decreased this abundance. The location of Lukun Village in the middle of Pulau Tebing Tinggi is associated with peat depths of 3 meters to 10 meters depth further inland towards forested areas (personal communication, Syaf, Head Badan Permusyawaratan (BPD) in Lukun Desa, 2024). This knowledge is based on information from the Peatland Restoration Agency (BRG-RI) and Universitas Riau, as Lukun is their research area.

Although *Redhang* water is accessible in Lukun, the perceived quality of *Redhang* water differs by location. The perceived quality is drinkable or undrinkable/contaminated. The environmental changes, including the existence of canals for company plantations and deforestation, cause drying and fires in dry seasons; and saltwater intrusion flows into the drying canals, causing brackish plantations of sago, rubber tree, and coconut trees. This causes redhang water to become contaminated and undrinkable in settlement areas. Since 2000, people living on the riverbank have moved further inland. At the same time, peat domes do not flow *Redhang* water to canals, decreasing the quantity of *Redhang* water (personal communication, Khairil 2024).

Although *redhang* water is still used for cleaning and bathing, adapting to the changes in quality and quantity of *redhang* water, people in Lukun utilise rain water and packaged water limitedly since 2000. People save rain water in a *perigi,* cemented container or tanks (see Figure 4). Besides, packaged water has become popular over the last 10 years. Nevertheless, people 50 years old or older and people with limited income still consume *rhedang* water. They still search the *Redhang water* far into the peat forest. They value *Redhang* water as fresh water located in the forest, under dense trees.

Water Related Adaptation to Settlement Pattern in Lukun Village

The peatland landscape in Lukun Village significantly influences settlement patterns, particularly in relation to water sources for daily needs. Houses are typically surrounded by spacious yards, forests, and sago plantations. Each settlement includes one or two shallow bathing wells nearby and a drinking well located behind the houses, illustrating a cultural practice of cleanliness,

Table 2. Perceived changes in the quality and quantity of redhang water in Lukun

Locations	Perceived Quality of Redhang Water	Perceived Quantity of Redhang Water	Associated Environmental Condition
Inland peatlands	Drinkable quality	Abundant	Pristine; surrounded by indigenous peat trees.
Settlement areas near riverbanks	Darker and no longer fresh due to sago waste contamination	Decreasing since 2000	Canals for plantations and deforestation since 1997.

Figure 4. Redhang water packaged in a bottle by a sago labourer

as residents traditionally clean their feet before entering. The arrangement reflects local knowledge passed down through generations. The settlement pattern in Lukun can be illustrated in Fig 5.

Figure 5. Settlement pattern considering peat landscape and water resource in Lukun Village

Historically, drinking wells were common due to the dense tree coverage, providing clean water for families and relatives. However, between 2003 and 2005, the area still had ample trees with minimal logging, allowing drinking wells to be found in nearly every household. Today, the prevalence of these wells has decreased as residents now rely on stored rainwater for their needs, with drinking wells primarily used for cleaning and bathing purposes.

Water Values for Malay People in Lukun Village

Malay people in Lukun value peat water (*rhedang* water) culturally, believes, and environmentally. Table 3 summarizes their values. Cultural value is generated from generation to generation, valuing peat water as thousand roots water having health benefit and locating in forest. This cultural value has an impact on settelement design, people approaching the peat water and design their settlement area based on water resources and uses. As Malay is mostly religious, it is convinced that water is gifted by God. Malay people also value rhedang water as means for transportation. It has led to their environmental value that canals shall be fullfilled by water yearlong, decreasing water in canal means the water is not available for consumption purposes as well. Nevertheless, borewell and rainwater is other sources for living.

Table 3 illustrates that water not only holds significant meaning in the lives of the Malay community in Lukun but also imparts additional values to the meaning of life. These values include local knowledge passed down from ancestors in understanding the cultural and religious functions of water. Furthermore, the significance of water has changed along with the transformation of the village landscape due to changes in the peat forest area.

Uses of Water Resources in Beting Village and Adaptation to Peat Degradation

Uses of Red Water in Beting Village, from Cleaning to Cooking

Red water or peat water in Beting village is a basic need for Orang Akit, which is affected by the geographical position of the village and the small income of the Akit people. Beting village is surrounded by a river flowing to *Air Hitam* Strait, enriched with mangrove forest standing 5-12 meters high. The mangrove forest is a source for the charcoal kiln. Orang Akit live with a small income as labourers of a charcoal kiln; as they cannot afford for “expensive” packaged water sold in Kota Selat Panjang, which is accessible by “expensive” transportation means. The village is far from access to harbor areas, and Pompong (a small boat) is the only transportation, and it is hardly affordable. This makes the Orang Akit mostly stay in the village (personal communication, Ahan, 2024). In addition, most Orang Akit cannot afford a tank to collect rainwater. They utilize the already available water, the red water, for daily needs (consumption and cleaning purposes) and build shallow wells in their yard to harvest the red water (Figure 6).

Orang Akit are dependent on natural resources as fishermen, mangrove harvesters, and charcoal laborers (Figure 7). The settlement areas are near coconut plantations, sago plantations, and forests. River ri-

Table 3. Water values for Malay people in Lukun

Informants	Views	Values
Amran (60, sago farmer & teacher)	*Redhang* water is "thousand roots water," believed to have healing properties. Traditional wells (*perigi*) were used for household activities.	Local knowledge and beliefs (cultural).
Anwar (57, village head)	Waste contamination from sago production has reduced freshness of *Redhang* water.	Cultural.
Lukman (56, *Tokoh Desa*)	*Redhang* water is a gift from God; rainwater used for drinking since 1997 due to scarcity.	Cultural and environmental.
Bu Anwar (46, housewife)	Rainwater shared among neighbors; packaged water for guests.	Cultural.
Cik Lili (46, housewife)	Prefers cooked rainwater for drinking; *Redhang* for working in forests.	Cultural.
Rina (42, housewife)	Rainwater for cooking, *Redhang* for bathing and washing.	Cultural.
A boy (32, logger)	*Redhang* water is fresh and available in forests, used for generations.	Environmental.
Suhai (26, teacher)	*Redhang* water essential for canals, irrigation, and transport.	Cultural and environmental.

verbank is the location of the charcoal kiln. Daily needs are bought in stalls in the village. Their limited access them has resulted in limited access to clean water, particularly packaged water.

Figure 6. Shallow well (perigi) of orang Akit in Beting village, Pulau Rangsang

Perceived Decreasing Quality and Quantity of Peat Water Due to Environmental Changes and Adaptation of People in Beting Village

It is figured out that Orang Akit heavily relies on red water to fulfil all aspects of their daily lives. The existence of Beting Village, situated on a small island, presents unique challenges regarding accessibility to the nearest village. This difficulty leads to a lack of alternative drinking water sources beyond red water and rainwater. Although rainwater has potential, it requires relatively expensive storage containers, which not all households can afford. Conversely, packaged water must be sourced from Selat Panjang, incurring high transportation costs, while borewells are rarely owned by the residents. The challenging economic conditions, where the majority of the community works as charcoal labourers, further contribute to their low income.

Red water serves as the primary source for the Orang Akit through the creation of small wells, locally known as "perigi." They believe that red water is a gift from nature—affordable and refreshing, making it unnecessary to purchase other types of water. These wells are typically constructed behind homes, sheltered by trees, and situated far from human access to prevent contamination from waste. Additionally, the river in the village is utilized for bathing and transportation. While some residents possess water storage containers, their quantities are limited and small in scale, rendering

Figure 7. Women labourers of charcoal kilns (left) and river water used for bathing, cleaning, and transportation

them insufficient to meet daily needs until the rainy season arrives. Consequently, red water remains the main drinking source for the village community. However, issues arising in Beting due to deforestation of forests and mangroves have made the village vulnerable to flooding. Residents are compelled to dig deeper wells and seek higher ground to prevent floodwaters from entering their settlements, dan charcoal mill waste. Additionally, wells located near the strait and river are experiencing pollution, resulting in saline water. This situation has persisted for the past ten years.

Table 4 illustrates that Orang Akit perceived peat water quality based on their locations. Peat water originated from inland peatlands is perceived as drinkable quality of water, this is because the inland peatlands are areas where indigenous peat trees are located and environmental condition are still pristine. Meawhile, peat water from settlement areas are contaminated by waste of charcoal mill and salt water instrusion. The peat water from this area is undrinkable. the environmental changes associate with forest and massive mangrove degradation in the last 10 years.

Water Related Adaptation to Settlement Pattern in Beting Village

The settlement in Beting village is situated on a small island in Pulau Rangsang, where red water is available for drinking inland. The settlement areas of the Orang Akit are adapted to their water usage and livelihoods. In addition to the red water from shallow wells, the Akit people utilize water from a river in the village for cleaning purposes. The settlement area of the Akit people is illustrated in Figure 8 below.

Charcoal kilns are located along the riverbanks, where mangrove trees are harvested. The river serves as a transportation route for the harvested mangroves to the kilns and for the charcoal to be transported outside the village. The drinking water wells are situated approximately 20 meters behind the houses, where most trees are located, and at a higher elevation than the houses to prevent contamination from domestic waste. The trees are regarded as protective barriers for the water source.

Figure 8. Settlement pattern of orang Akit in Beting Village adapted to river uses and red water uses

Water Values for Orang Akit in Beting Village

Orang Akit value water based on belief, cultural, environmental impacts, and socio economi impacts. Table 5 summarizes their values. Orang Akit value water as water is a gift from nature (unlike malay people value it as a gift from God). This value has been

Table 4. Perceived changes in the quality and quantity of redhang water (red water) in Beting

Locations	Perceived Quality	Perceived Quantity	Associated Environmental Condition
Inland peatlands	Drinkable	Abundant	Pristine forest peat.
Settlement areas near riverbanks	Contaminated by charcoal mill waste and saltwater intrusion.	Damaged in the last 10 years.	Forest and mangrove degradation over the past decade.

associated with how forest and mangrove degradation has led to decreasing water and difficulties in gathering water. Cultural value is that Orang Akit value water as heritage. This heritage has contributed to their daily living; whereas packaged water is a new economic burden and rainwater is limitedly used.

Uses of Water Resources in Selat Panjang And Adaptation to Peat Degradation

Uses of Red Water in Selat Panjang, from Cleaning to Cooking

In Selat Panjang, residents rely on four primary water sources for various purposes. Red water (redhang) and white water are mainly used for cleaning, while rainwater is utilized for cooking and bathing when available. During periods of limited rainfall, Selat Panjang residents access clean water as packaged water and rainwater from Tionghoa to fulfil their needs.

The Tionghoa community living along the Air Hitam Strait predominantly depends on rainwater, constructing large ponds to collect it for the dry season. These ponds, frequently located beneath their shops, serve as vital resources. Tionghoa traders sell rainwater in 30-liter containers for Rp 10,000 to Rp 30,000, especially during dry seasons when demand surges. The initial investment for a 3x4x4 meter pond was Rp 70,000,000 in 1997, a cost likely higher on the mainland due to transportation challenges from Batam. For the Tionghoa, these ponds represent a long- term investment that benefits both their community and others during dry periods.

Other ethnic groups in Selat Panjang, such as the Javanese and Malay, reside 1-2 km inland and utilize 2-5 tanks (mostly 300-1000 L) for rainwater collection. They primarily use rainwater for cooking, while relying on red and white water from bore wells for cleaning. However, the salty white water is unsuitable for drinking or cooking. Many in this group also use packaged water, but the tanks often do not meet household demands, and borewell water has an unpleasant taste and smell due to its high iron content.

Perceived Decreasing Quality and Quantity of Peat Water Due to Environmental Changes and Adaptation of People in Kota Selat Panjang

Our interviews elicited that the quality and quantity of peat water have decreased in the past 30 years in Selat Panjang (shortly described in Table 6). The deforestation has negatively impacted both the quantity and quality of red water in wells. Since the 1980s, wood factories have emerged in Selat Panjang, contributing to deforestation and a perceived decrease in peat water quantity and quality. In addition to the degradation, an increasing population has resulted in a scarcity of red water for consumption. Consequently, water harvested from borewells constructed by the community is salty, suitable only for bathing and washing. Peat degradation has decreased the peat thickness, as the deepest peat is now only 1 m deep. This has an impact on decreasing water stored in peatlands (a decrease in water quantity in shallow wells).

Furthermore, the declining quality and quantity of peat water have led to a wider adoption of rainwater collection sin-

Table 5. Views and values of Orang Akit regarding water resources in peat ecosystem

Informants	Views	Values
Alin (23, charcoal kiln worker, housewife)	*Red* water is a gift; deforestation causes flooding and contamination.	Beliefs and environmental impact.
Ate (23, charcoal kiln worker)	Health office warned of acidity, but villagers still consume due to lack of alternatives.	Public health and accessibility.
Abok (35, mangrove logger)	*Red* water accessible since ancestral times, considered safe.	Social-cultural heritage.
Afang (20, housewife & kiln worker)	Bathing in *red* water from canals is traditional.	Cultural practices.
Apo (27, kiln worker)	Uses *red* water for bathing and cooking; social interaction during bathing.	Cultural and social.
Ajo (50, fisherman)	Rejects claim that *red* water causes health problems; considers it fresh.	Cultural beliefs and health perception.

ce the late 1990s. Cemented water containers have been imported from Malaysia to store rainwater, and by the 2000s, fiber water tanks were introduced, followed by the emergence of packaged drinking water. Malay residents living inland still have access to shallow wells, but the water quality is not suitable for drinking, leading to reliance on bottled water and rainwater. The Tionghoa ethnic along the Air Hitam Strait collects rainwater in large tanks for trade and culinary purposes, while coastal water remains salty.

Water Related Adaptation to Settlement Pattern In Selat Panjang

In Selat Panjang, the settlement pattern has an impact on the choices of water (Fig 9). As the capital city of Kepulauan Meranti regency, instant drinking water is available in stalls and shops. Some shops produced packaged water distributed in big gallons and small bottles. Rainwater is the main water supply in this area, as its citizens can equip their houses with water tanks to collect rainwater. Kota Selat Panjang is a populated area and a centre for trading, limiting the establishment of bore wells. Unlike Tionghoa, other ethnicities living in Selat Panjang (and other places in Pulau Tebing Tinggi) have a spreading pattern of settlement areas

Figure 9 shows the settlement pattern of the Tionghoa people in Selat Panjang. They settle on the edge of the Air Hitam Strait along Kota Selat Panjang. Their houses function as housing and shops (rumah toko/ruko), supporting their trading. They are equipped with transportation on the small island, also supporting their trading. Borewell water is not suitable in this area, resulting in their choice to use rainwater. They are more dependent on rainwater than other ethnic groups.

Water Values for Ethicities in Selat Panjang

Water values for ethnicities in Selat Panjang are distinguished from Malay (Table 7), Javanese (Table 8) and Tionghoa (Table 9). Malay people in Selat Panjang value more rainwater than peat water. Their values are based on health associating with peat water quality and environmental degradation leading to brackish to borewell. Similarly, Tionghoa also value water based on health, with opportunity to develop their economic value. Although, the economic value is sometimes counterproductive with their religious value (*a gift from god we cannot sell*). As for Javanesse, we compare javanese in Lukun from Javanese in Selat Panjang. It is figured out that Javanese in Selat Panjang value rain water more than peat water, and

Table 6. Perceived changes in quality and quantity of redhang water (red water) in Selat Panjang

Locations	Perceived Quality	Perceived Quantity	Associated Environmental Condition
Peat within the island (used for plantations)	Not suitable for drinking; used for bathing/washing.	Peat dries up in dry season.	Forest depletion; peat on outskirts.
Settlement near riverbanks	Not used.	None.	No forest and peatland nearby.

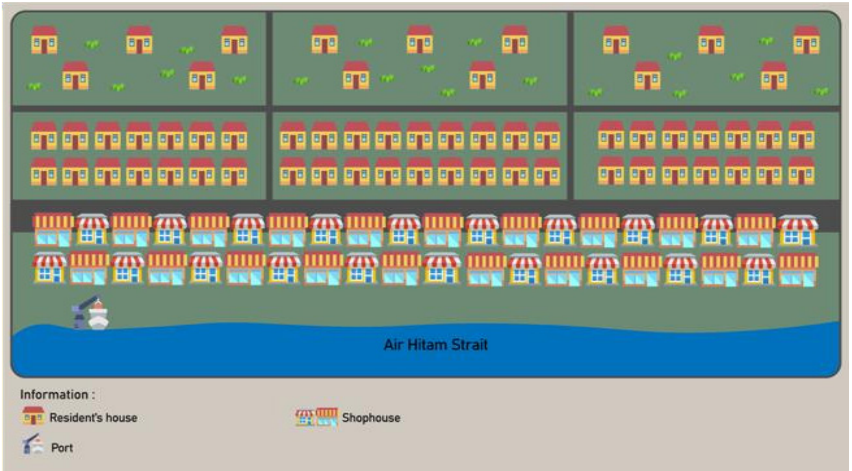

Figure 9. Settlement pattern of Tionghoa in Kota Selat Panjang

the rainwater has economic value. Meanwhile, Javanese in Lukun value more rhedang water in pristine forest and acknowledge environmental degrdation affecting peat water and borewell.

The perspectives of the Malay and Javanese communities in Selat Panjang regarding the value of water are quite diverse (see Tables 8 and 9). Water holds significant economic value for trade activities. On the other hand, the community's views on health and illness related to water usage differ from those of the government. Additionally, water serves as an indicator of ecological changes and poses challenges for the community to continually adapt to environmental and market changes.

In Table 9, the Tionghoa views that water has economic, eligious and socio-cultural values. Water, as a gift from God, should not be sold, as it is obtained for free. In terms of economic value, Tionghoa sell the water to residents in appropritate times (dry season). They also view it as a socio-cultural value by helping others.

Clean water in Kepulauan Meranti is rather a perceived value than parameterized water quality indicators. People in Lukun and Beting mostly perceive peat water (as called *redhang* or *Air Merah*) as a clean water source and drinkable. People in Selat Panjang mostly perceive that rainwater and packaged water are clean water sources and drinkable. People's choices of water exemplify environmentally adaptive choices. The adaptation concept has been used in some disciplines to learn human activities in supporting people to sustain their living (Aniah et al., 2019; Chen et al., 2023; Steger et al., 2024). Human beings choose expected strategies through their ability to adapt to natural external conditions. The adaptation as such is caused by landscapes, hydrology, climate, and limited natural resources. Indigenous people more strongly adapt to the natural resources (Pei et al., 2020), and in this study, we found that the Akit people in Beting village are more strongly adaptable.

Besides, utilizing available natural resources is are subjective awareness (Dastgerdi et al., 2020). This study implies that choices of water sources are in harmony bet-

Table 7. Views of Malay in Selat Panjang regarding water resources

Informants	Views	Values
Marzuki (65, retired officer)	People avoid *red* water; use rainwater in cement ponds.	Health & environment.
Rudi (52, officer)	Government neglects clean water issue; villagers rely on *red* water.	Health & policy.
Tengku (50, employee)	*Red* water unhealthy (acidic, causes tooth decay).	Health.
Henry (47, civil servant)	Rainwater harvesting training failed due to cost.	Economic & policy.
Santi (28, SHS graduate)	Laundry businesses use *red* water, rinse with rainwater.	Economic & environmental adaptation.
Ikhsan (25, PNS)	Packaged water for drinking, borewell for cleaning.	Health.
Arif (27, student)	*Red* water has low pH; rainwater better for cooking/drinking.	Health.

Table 8. Views and values of Javanese in Lukun and Selat Panjang regarding water resources in peat ecosystem

Informants	Views	Values
Syaf (58, Lukun)	*Redhang* water light and clear; scarcity due to deforestation; uses borewell (salty) and rainwater.	Environmental adaptability.
Sita (23, Selat Panjang)	Collects or buys rainwater; coffee sellers store large quantities to sell.	Economic adaptability.

Table 9. Views and values of Tionghoa in Selat Panjang regarding water resources in peat ecosystem

Informants	Views	Values
Alan (35, trader)	Rainwater is a divine gift; helps people by selling it affordably.	Health · Religious · Economic.
Afan (30, trader)	Collects rainwater in large ponds for family and business.	Economic.
Robert (29, trader)	Uses only rainwater; finds packaged water strange-tasting; borewell is salty.	Health & Economy.

ween nature and knowledge, resulting from local cultural construction. People live closer to natural resources, in this case is water resources. People adapt to the changes in perceived quality due to environmental degradation. This case is gathered from the choices of people in Lukun, where rainwater is mostly used after their people perceived changes in water quality due to changes in environmental quality. Meanwhile, in Kota Selat Panjang, more choices are selected for non-peat water as they perceive low quality of peat water, and their economic resources are more reliable than it is in Lukun and Beting.

To compare perceived values of the people in Kepulauan Meranti, people in the Indonesian archipelago differ in their perception of peat water. Local communities of peatlands perceive peat water differently from the government and scientists. Local communities of peatlands use peat water for consumption because they have been adapted to their areas (Bhatta et al., 2019; Ken et al., 2020; Platt et al., 2021). This results in different development interventions for supplying clean water (Campos et al., 2016) as well the suitable water for consumption (Adhikari & Taylor, 2012). The government and scientists may refer to the standard of clean water, which are not smelly, colourless, not tasty, does not contain microbes and chemical contaminantats (Farhan et al., 2023; Indramayu, 2022; Permenkes RI, 2010); causing the red water, sour peat water does not meet clean or drinking water criteria; although in some villages people consume peat water like in Lukun and Beting. Local peat people learn from their nature, perceive inherited values about peat water suitability for uses and consumption, even without cooking it; this is a cultural dynamic. Meanwhile, the standards of clean water require peat water as a low pH water (Said et al., 2019) to meet the health standard of normal pH (Musadad, 1998) and prevent water diseases (Agustina et al., 2021; Musadad, 1998). This implies that local adaptation of people living in peat ecosystems is absent in developing governmental agendas (Hosen et al., 2020); nevertheless, the government is required to assist accessibility of rainwater to vulnerable locals and indigenous people.

CONCLUSION

There are four sources of water used by local communities in Kepulauan Meranti, Riau Province. They are peat water named locally as rhedang water in Lukun and air merah (red water) in Beting and Selat Panjang, borewell water (white water), rain water, and packaged water. The quality of the four water sources is differently perceived, associated with environmental, religious, cultural, and economic values, affecting their strategies to adapt to gather clean water. Rainwater is a clean water source accessible to all ethnicities in different ways, related to their livelihood. Orang Akit are the most adaptable to peat water. They are also the most vulnerable society to clean water scarcity. This vulnerability is associated with exposure to a mostly decreasing quantity and quality of peat water. They have limited resources to access cleaner water, like rainwater.

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