

Water Suitability for Paddy Field Irrigation in Tropical Watershed Dominated by Ancient Volcanic Rocks and Limestones, Indonesia

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Abstract

Proper water quality for plant growth is important to ensure high productivity in food production. However, the hydrological and geological characteristics of a region cause distinctive characteristics that need to be understood in order to carry out proper agricultural practices. The purpose of this study was to determine the temporal variation of Tesih River water suitability for irrigation. This research is expected to provide an overview of the temporal variation of water suitability for irrigation in a watershed dominated by ancient volcanic rocks and limestone that have formed karst areas. On the other hand, this study is expected to provide an overview of the influence of climatological conditions controlled by tropical climate and the characteristics of the Asian-Australian monsoon winds at the study site that are strong on water suitability for irrigation. Methods used: Percent Sodium (Na%), Sodium Adsorption Ratio (SAR), Wilcox diagram, USSSL diagram, Hardness (H), Magnesium Hazard (MH), Kelly's ratio (KR), Permeability Index (PI), and Residual Sodium Carbonate (RSC). The water suitability methods used were percentage of sodium (Na%), sodium adsorption ratio (SAR), Wilcox diagram, USSSL diagram, hardness (H), magnesium hazard (MH), Kelly's ratio (KR), permeability index (PI), and residual sodium carbonate (RSC). The analyses showed that the river water was good (based on Na%, USSSL diagram, and RSC), very good (SAR and PI), excellent (the Wilcox diagram), or suitable for irrigation (H, MH, and KR). Overall, the river has the physical and chemical qualities suitable for supporting crop growth without damaging soil properties.

Keywords:

Paddy Field Irrigation, Karst, Ancient Volcanic Rock, Water Quality, Hydrogeochemistry.

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1. Introduction

Irrigation is the key component of agricultural practices (Döll and Siebert, 2002; Šimunić et al., 2021; Mohammed et al., 2025). Irrigated farmlands account for an estimated 20% of the global agricultural area, contributing approximately 40% of annual food production (Mohtar and Fares, 2022). However, irrigation is perceived as one of the most uneconomical forms of water utilisation. On average, the agricultural sector constitutes around 70% of freshwater needs worldwide and almost 90% in developing

countries (FAO, 2017). It is therefore encouraged to implement increasingly productive cultivation systems that use water efficiently (Al-Obeidi et al., 2025).

The need for irrigation water rises every year (Abdoulaye et al., 2019) as a result of population growth and changes in lifestyle, with inevitably increasing food demand (Telteu et al., 2021; Salem et al., 2022). In line with this, Day (2019) calculated that the global water needs in 2050 would be 55% greater than in 2000. For irrigation water, supplies can come from rainwater, surface water (including rivers, lakes and swamps) and groundwater (Starr et al., 2014; Samardžić et al.,

2022). However, rivers have long been the most common and main source of irrigation (Tickner *et al.*, 2017), comprising 60% of total irrigated land that produces around 24% of global food supplies.

To determine suitability for controlled watering of farmlands, water sources are usually evaluated for their quantity and quality before distribution (Šoškić *et al.*, 2001; Al-Saffah and Al-Mashhadany, 2025). Water quantity analysis incorporates infrastructure and total land area to be irrigated, whereas water quality assessment aims to ensure farm productivity and effective plant treatment (Šoškić *et al.*, 2001; Tanaskovikj *et al.*, 2014; Kateb and Al-Youzbakey, 2025) while preventing land or soil deterioration (Paruch *et al.*, 2015; Ismail *et al.*, 2019; Hafiane *et al.*, 2020). The latter is, however, conducted less frequently than the former. Water with unsuitable chemical and physical qualities can lead to suboptimal crop growth and even crop failure and soil damage in some cases (Abbasian *et al.*, 2014; Ibrahim and Al-Youzbakey, 2024).

Indonesia is an agrarian country where the agricultural sector produces a considerable amount of food and plays a crucial role in its economy (Maat, 2014), with around 14% contribution to the country's gross domestic product (GDP) (Barichello and Patunru, 2009). This further affirms the importance of monitoring and fulfilling irrigation water needs, which have been found to constantly increase by about 20% between 2000 and 2020 (Tirtalistyani *et al.*, 2022). This upward trend has also been predicted to continue as a result of farmland expansion to achieve food self-sufficiency (Fulazzaky, 2017; Ma'Mun *et al.*, 2021). Like the research trend worldwide, many studies have been performed on water quantity or availability for irrigation in Indonesia (Mediawan *et al.*, 2021; Khasanah *et al.*, 2021), but only a few have been conducted on water quality and its multitemporal variations. A multitemporal study can shed light on the hydrogeochemical characteristics of water, which are closely related to the seasons and change over time as a result of contact or interaction between groundwater and rocks.

In line with this, the research uses the Tesih Watershed as an example because (1) it is situated in a rural region where rice fields and dry farmlands occupy most of its area and (2) it has unique geological features. The watershed is 12.22 km² and lies on ancient volcanic rocks and

limestones that form karst landscapes in Sawahan and Tambakromo Villages, Ponjong District, Gunungkidul, Indonesia (Fig. 1). Geologically, it is located on the Semilir and Wonosari Formations composed of reef limestones (Rahardjo, 1995). Semilir Fm of the Early Miocene age covers the largest area of the watershed (9.78 km²). It consists of lapilli tuffs with intrusive tuffs and tuff clays, tuff sandstones, pebbly sandstones, and pumice breccia. Wonosari Fm (2.44 km²) was formed in the Middle to Late Miocene and consists of layered limestones, massive limestone, marl-tuff, and sandstones (Adji *et al.*, 2019). Wonosari Fm is part of the Gunungsewu Karst Area in the Ponjong Hydrogeological Subsystem (Kusumayudha, 2009). In addition, the watershed receives about 2,000–3,000 mm of rainfall per year (Cahyadi *et al.*, 2021).

This research aimed to analyse the suitability of water in the Tesih Watershed for irrigation multi-temporally. It collected water samples every two weeks for one year to describe the temporal variations of water quality in a watershed on ancient volcanic rocks and karstic limestones. It also explains the influence of tropical climate controls and the strong Asian-Australian monsoon winds (Cahyadi *et al.*, 2021) on the water's suitability. The Asian-Australian monsoon winds have contrasting characteristics: wet in the rainy season and very dry in the dry season (Riyanto *et al.*, 2020).

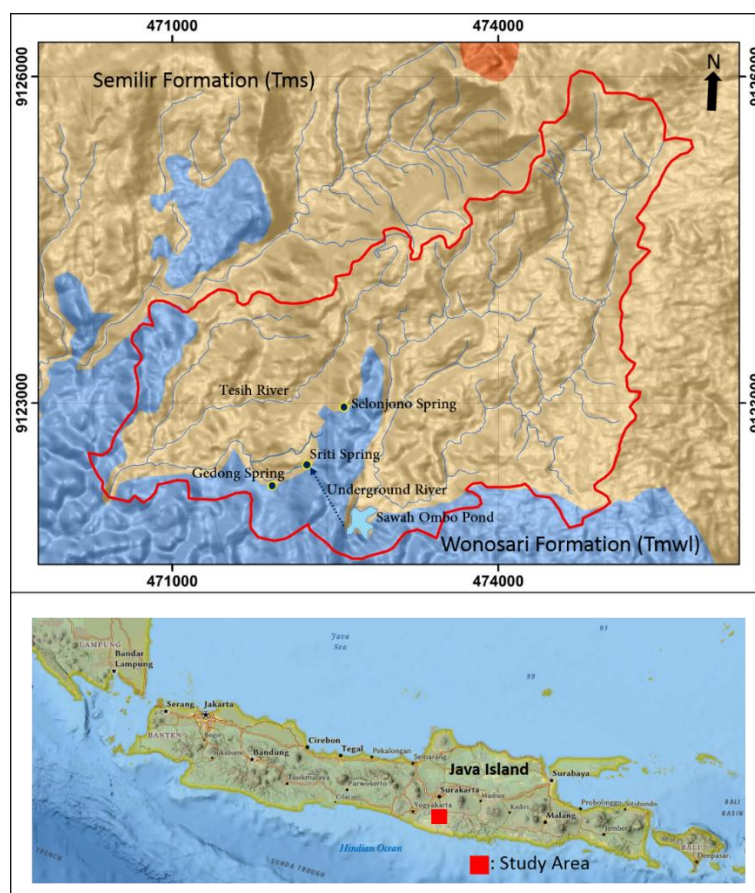


Fig. 1: Location of the Tesih Watershed on Java Island, Indonesia (Sources: Topographic Map in 1:25,000 scale from the Geospatial Information Agency, Geological Map in 1:50,000 scale from the Geological Agency, and maps provided by <https://esri.com/natgeomapmaker>)

2. Materials and Methods

From 2020 to 2021, twenty-five water samples were collected from the Tesih River during the dry and rainy (wet) seasons, with a sampling interval of two weeks. Samples therefore represent the different seasonal conditions and influences throughout the year (Dragović, 2012). In the field, a water quality test kit was used to measure temperature, pH, electrical conductivity (EC), and total dissolved solids (TDS), and an alkalinity test kit to analyse HCO_3^- by titration. Further, the samples were tested in the laboratory to determine Ca^{2+} , Mg^{2+} , Na^+ , K^+ , Cl^- and SO_4^{2-} concentrations.

Table 1 details the equation and classification of nine different methods used to assess water suitability for irrigation. Comparing multiple methods can determine their respective degrees of sensitivity to data variation because they use different parameters and equations (Wilcox, 1955;

McGeorge, 1954; Bhat *et al.*, 2018; Cahyadi *et al.*, 2023a). Besides, it allows cross-evaluation or validation of one method with another, particularly in analysing water suitability for irrigation that incorporates numerous aspects of water quality, plant productivity, and preventive measures against crop failure (Mohammed, 2021). The water suitability analysis also factors in land cultivation, fertilisation and the addition of certain elements for effective, efficient and target-specific soil enrichment (Nishanthiny *et al.*, 2010; Ayers and Westcot, 1985). K^+ and Cl^- were not included in the assessment, but both ions were input into the charge-balance error (CBE) equation to ensure the quality of the hydrogeochemical data used in this research.

Table 1: Water quality equations for irrigation purposes.

Method	Equation	Classification (C)
Na%	$\frac{(Na + K)100}{(Ca + Mg + Na + K)}$	S1 < 20 Excellent (E)
		S2 20–40 Good (G)
		S3 40–60 Permissible (Pe)
		S4 60–80 Doubtful (D)
		S5 >80 Unsuitable (Un)
Sodium adsorption ratio (SA)	$\frac{Na}{\sqrt{1/2}(Ca + Mg)}$	S1 <10 Excellent (E)
		S2 10–18 Good (G)
		S3 18–26 Fair (F)
		S4 >26 Poor (Po)
Wilcox	Diagram-based, correlating two parameters: Na% and EC	Excellent to Good (EG)
		Good to Permissible (GP)
USSL	Diagram-based, correlating two parameters: SAR and conductivity	Doubtful to Unsuitable (DU)
		Unsuitable (Un)
		C1S1 Good (G)
		C1S2 Moderate to Good (MG)
		C1S3 Moderate (M)
		C1S4 Moderate to Poor (MP)
		C2S1 Moderate to Good (MG)
		C2S2 Moderate (M)
		C2S3 Moderate to Poor (MP)
		C2S4 Poor (P)
		C3S1 Moderate (M)
		C3S2 Moderate to Poor (MP)
		C3S3 Poor (P)
		C3S4 Very Poor (VP)
		C4S1 Moderate to Poor (MP)
		C4S2 Poor (P)
		C4S3 Very Poor (VP)
		C4S4 Unusable (U)
Hardness/H (CaCO ₃)	2.5 (Ca)+4.1(Mg)	<75 Soft (Sf)
		75–150 Moderate (M)
		150–300 Hard (H)
		>300 Very Hard (VH)
Magnesium hazard (MH)	$\frac{Mg}{Ca+Mg} \times 100$	≤50% Suitable (S)
		>50% Unsuitable (Un)
Kelly's ratio (KR)	$\frac{Na}{Ca+Mg} \times 100$	≤1 Suitable (S)
		≥3 Unsuitable (Un)
Permeability index (PI)	$\frac{Na + \sqrt{HCO_3}}{Ca + Mg + Na} \times 100$	<25% Unsuitable (Un)
		>25% Good (G)
Residual sodium carbonate (RSC)	$(HCO_3 + CO_3) - (Ca + Mg)$	(-) Very Good (Vg)
		0–1.39 Good (G)
		>1.39 Unsuitable (Un)

Source: Cahyadi *et al.* (2023a)

3. Results and Discussion

Table 2 presents the chemical analysis results of the river water samples, including CBE values and major ion concentrations on each day of measurement. The CBE varied from -9.6 to 12.4 with an average of <10%, meaning the data obtained using the field analysis kits and laboratory tests are acceptable for further hydrogeochemical analysis to evaluate water suitability for irrigation. As the table shows, the major ions in the study area formed different patterns of temporal variations throughout the

year. Calcium and bicarbonate ions were detected at larger concentrations than the other ions. This particularly illustrates the substantial influence of karst aquifers even though karst landforms occupied only 20% of the Tesih Watershed area.

Fig. 2 shows that calcium and bicarbonate tended to have lower concentrations in the wet season than in the dry season. The trend is closely related to dilution by rain and interaction between water and rock (Pratama *et al.*, 2021), especially the limestone of Wonosari Fm. This effect was also seen from the drastic increases in calcium and carbonate concentrations in the dry season, during

which only the water carrying both ions from the karst aquifer fed the Tesih River. Ancient volcanic rocks are generally not good aquifers as they partition most rainwater into surface runoff. As a result, surface water drains quickly during the wet season without seeping into the soil, often leaving little to no groundwater storage during months of no rain. Accordingly, instead of rain and surface runoff, water from three perennial karst springs (Cahyadi *et al.*, 2023b) recharges the Tesih River in the dry season. These springs are Selonjono, Gedong, and Sriti (see Fig. 1). Sriti is a resurgence of an underground river (Cahyadi *et al.*, 2022a), while Selonjono and Gedong are epikarst springs (Cahyadi *et al.*, 2022b).

Fig. 3 shows that, unlike calcium and bicarbonate, the concentrations of the other major

ions (magnesium, potassium, sodium, chloride, and sulphate) varied less considerably or did not show a substantial change over the observation period. An exception was identified in sulphate ions, whose concentration rose drastically at the beginning of the second wet season (October-November 2020). This condition likely results from anthropogenic pollution, especially from agricultural lands that are usually left bare or uncultivated in this period. It leads to runoff with high erosion rates that easily removes and carries soil particles and chemical elements typical of farming practices, such as sulphate, downstream, increasing their presence in the waters (Huebsch *et al.*, 2014; Chen *et al.*, 2020). As crops grow, their roots retain more residues and eventually decrease sulphate concentrations in the river.

Table 2: Water quality equations for irrigation purposes.

Date	Ca ²⁺	Mg ²⁺	Na ⁺	K ⁺	Cl ⁻	HCO ₃ ⁻	SO ₄ ²⁻	CBE
17/02/2020	37.41	3.87	5.00	1.00	3.00	134.24	2.00	2.1
09/03/2020	32.00	16.52	8.00	1.00	3.50	213.56	14.00	-7.8
16/03/2022	62.09	7.89	10.00	1.00	3.00	244.06	12.00	-1.5
30/03/2020	49.00	7.74	7.00	2.00	2.50	231.86	14.00	-9.5
13/04/2020	52.80	9.72	9.00	2.00	4.50	219.66	12.00	-1.3
28/04/2020	56.62	11.60	16.00	2.00	5.00	231.86	15.00	3.1
12/05/2020	50.15	15.47	9.00	2.00	5.00	219.66	9.00	3.6
28/05/2020	55.72	12.09	13.00	2.00	6.00	213.56	18.00	4.1
06/06/2020	105.20	18.46	9.00	1.00	3.50	396.60	7.50	6.3
22/06/2020	106.27	15.72	11.00	1.00	3.25	433.21	6.00	-4.2
06/07/2020	104.80	11.18	11.00	1.00	3.75	405.76	6.00	-1.8
20/07/2020	114.40	10.94	9.00	1.00	3.75	427.11	17.00	-2.7
03/08/2022	111.04	11.37	7.00	1.00	3.25	424.06	4.00	0.9
18/08/2022	116.58	13.44	6.00	1.00	3.50	414.91	9.50	-1.6
31/08/2022	115.20	10.21	6.00	1.00	3.50	408.81	7.00	-5.9
19/09/2020	107.34	12.96	5.00	1.00	3.50	445.42	6.50	-9.6
26/09/2020	82.00	16.77	7.00	1.00	3.00	408.81	6.50	-0.3
12/10/2020	85.17	13.54	3.00	1.00	3.40	335.59	6.50	-4.2
26/10/2020	100.80	6.08	6.00	1.00	8.90	363.05	7.00	12.4
09/11/2020	32.00	16.04	9.00	3.00	4.00	128.13	28.00	9.5
26/11/2020	34.00	6.36	11.00	2.00	4.50	85.42	38.00	8.5
07/12/2020	39.60	5.40	9.00	2.00	4.50	128.13	20.00	4.0
21/12/2020	46.87	2.95	12.00	2.00	4.50	164.74	21.00	-1.7
04/01/2021	30.25	6.29	7.00	1.00	3.50	122.03	23.00	-4.5
19/01/2021	48.00	14.58	6.00	2.00	4.00	207.45	9.00	2.7

Notes: Major ion concentrations are expressed in mg/L and CBE in %

Source: Direct measurements in the field and laboratory analyses

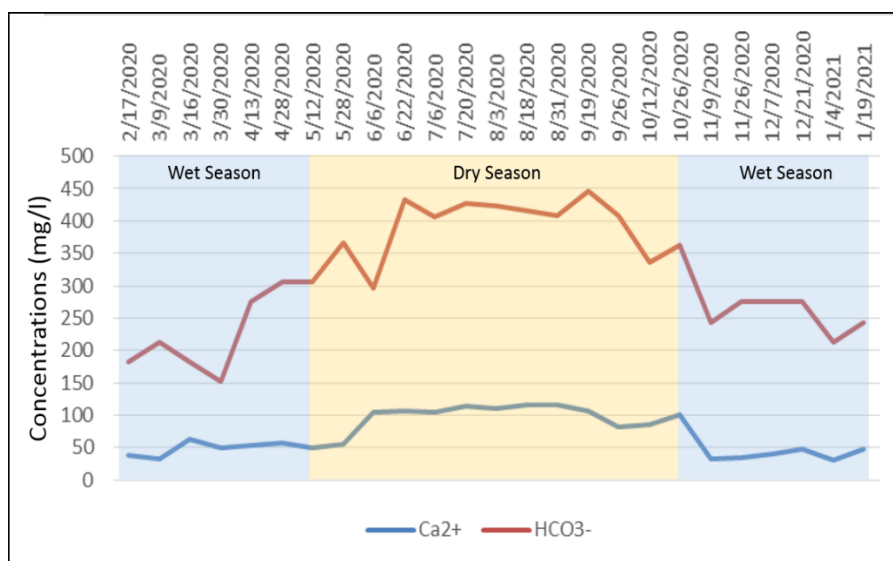


Fig. 2: Temporal variations of calcium and bicarbonate ions in the Tesih River

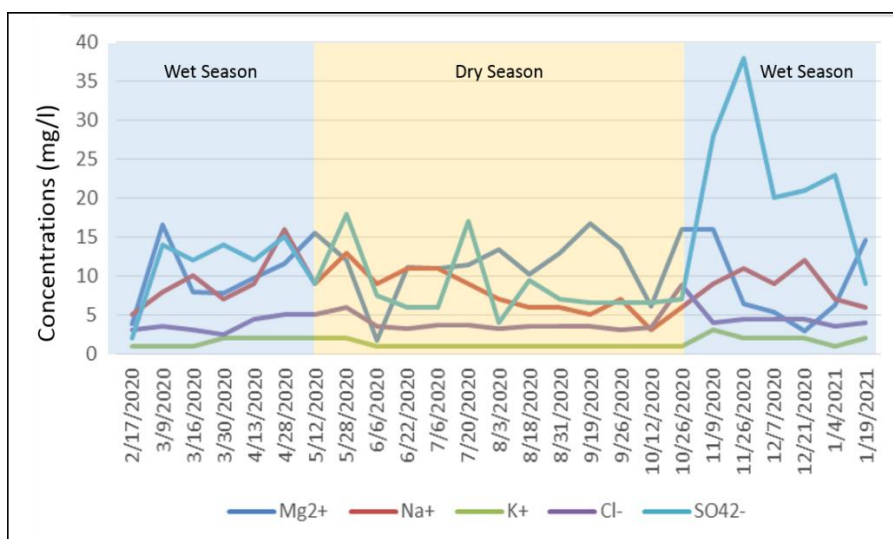


Fig. 3: Temporal variations of magnesium, sodium, potassium, chloride and sulphate in the Tesih River

Table 3 shows the physical analysis results of the water samples, including pH, TDS, temperature, SAR and Na%. The data obtained indicate that pH, EC and TDS had the same temporal pattern, where their concentrations tended to be higher in the dry season than the wet season. Similar to major ions, this pattern results from dilution by rain during the wet season and intensified water-rock interaction that is predominant during the dry season (Ramadhan *et al.*, 2021).

The pH levels were in the range of 6.29–8.76 (mean=7.63) in the wet season and 7.91–8.62 (mean = 8.21) in the dry season. Despite the temporal variation, these data suggest alkaline water and thus indicate the dominant effect of karst aquifers, which generally have high pH (Adji *et al.*, 2017; Pratama *et al.*, 2021; Mahrizkhal *et al.*, 2022). This finding further supports the chemical analysis results that identified the presence of calcium and bicarbonate ions in the river, which are indicative of water flowing in and from a karst hydrogeological system. The EC levels varied from 190 to 355 $\mu\text{S}/\text{cm}$ (mean=288.25 $\mu\text{S}/\text{cm}$) in the wet season and from 338 to 594 $\mu\text{S}/\text{cm}$ (mean = 507.77 $\mu\text{S}/\text{cm}$) in the dry season. TDS was detected at 100–180 ppm (mean=288.25 ppm) in the wet season, or lower than in the dry season, 169–315 ppm (282.31 ppm). Even though the EC and TDS levels tended to be higher during the dry season, they were still considered very suitable (excellent to good) for agricultural irrigation, according to the Wilcox method (Wilcox, 1955).

Table 3: Physical parameters, sodium adsorption ratio (SAR) and percentage of sodium (Na%)

Date	pH	TDS (ppm)	Temp. (°C)	SAR	C	Na%	C
17/02/2020	8.76	110	27.8	0.21	E	10.	E
09/03/2020	7.68	153	29.2	0.29	E	11.2	E
16/03/2022	8.05	175	26.9	0.32	E	10.9	E
30/03/2020	8.02	174	28.0	0.25	E	10.9	E
13/04/2020	7.73	170	28.1	0.30	E	11.4	E
28/04/2020	8.15	178	30.8	0.51	E	16.5	E
12/05/2020	8.12	174	27.3	0.28	E	10.5	E
28/05/2020	7.91	169	30.4	0.41	E	14.0	E
06/06/2020	8.62	292	27.1	0.21	E	5.8	E
22/06/2020	8.23	310	26.7	0.26	E	7.1	E
06/07/2020	8.21	310	26.0	0.27	E	7.6	E
20/07/2020	8.16	310	26.6	0.22	E	5.9	E
03/08/2022	8.01	315	25.1	0.17	E	4.8	E
18/08/2022	8.07	310	28.0	0.14	E	4.0	E
31/08/2022	8.35	315	27.0	0.14	E	4.2	E
19/09/2020	8.33	310	26.0	0.12	E	3.6	E
26/09/2020	8.24	310	26.5	0.18	E	5.7	E
12/10/2020	8.15	250	26.4	0.08	E	2.8	E
26/10/2020	8.30	295	26.3	0.16	E	4.9	E
09/11/2020	6.78	120	28.4	0.32	E	13.8	E
26/11/2020	7.50	140	27.3	0.42	E	16.8	E
07/12/2020	7.29	140	26.5	0.36	E	15.5	E
21/12/2020	6.29	150	26.4	0.46	E	18.2	E
04/01/2021	7.61	100	26.1	0.30	E	14.0	E
19/01/2021	7.64	180	26.2	0.19	E	8.0	E

Notes: C (Classification) and E (Excellent)

Wet Season

Dry Season

Source: Direct measurements in the field and laboratory analyses

As seen in Table 3, the SAR of the Tesih River was in the range of 0.19–0.46 (mean=0.33) in the wet season and 0.19–0.41 (mean = 0.31) in the dry season. Na% varied from 8.0 to 18.2 (mean=13.1) in the wet season and from 2.8 to 14.0 (mean=11.8) in the dry season. Both parameters had very similar temporal patterns: their levels were higher in the wet than in the dry season (Fig. 4), which can be linked to the presence of calcium. Intensive water-rock interaction during the dry season increases calcium levels, thus reducing SAR and Na%. Several other karst springs in the Ponjong Hydrogeological System of the Gunungsewu Karst Area, namely Selonjono, Gedong and Beton, also show the same temporal variation (Cahyadi *et al.*, 2020a; 2020b; Cahyadi *et al.*, 2022; 2023b). Despite their wide range of values, SAR and Na% were relatively low and were thus categorised as excellent throughout the year. Low SAR and Na% mean the river water is less likely to damage soil properties, harden soil,

disrupt infiltration, or decrease hydraulic conductivity, aggregate stability, and drainage capacity when used for irrigation (Naseem *et al.*, 2010; Dragović *et al.*, 2012; Shah and Mistry, 2013; Patil and Nagarajan, 2015).

The Wilcox diagram analysis revealed that all the water samples of the Tesih River were categorised as Excellent to Good (Fig. 5), which is the best grade in the classification. This means that even though the Wilcox diagram incorporates EC and Na%, the results are the same as the suitability classification using Na% alone. The USSL analysis categorised the water samples into Moderate to good (C2S1) and Good (C1S1); both are also the highest levels in the USSL classification (Fig. 6). The USSL diagram has the most classes (16) among the nine methods used in this research and thus provides more detailed results. In this case, what appears to be ‘Excellent to good’ in the Wilcox classification can be further divided into ‘Moderate to good’ and ‘Good’.

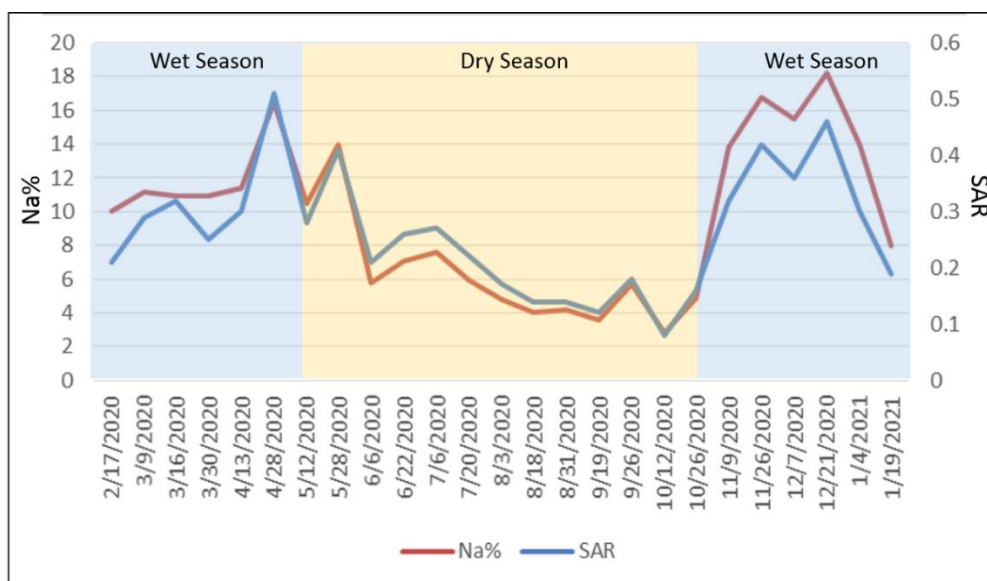


Fig. 4: Temporal variations of Na% and SAR in the Tesih River

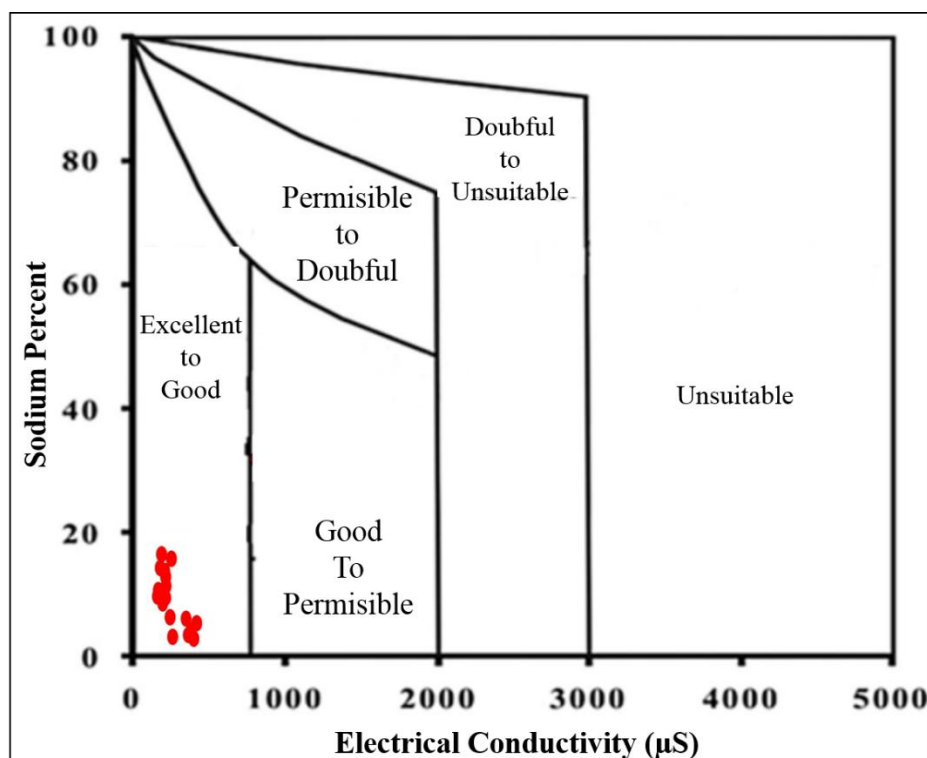


Fig. 5: Wilcox diagram of the Tesih River

Table 4 shows the results of water suitability analysis for irrigation using residual sodium carbonate (RSC), permeability index (PI), magnesium hazard (MH), Kelly's ratio (KR), and hardness (H). Only RSC and H showed variations in the water suitability classification. PI, MH, and KR analyses placed the river water into Good and Suitable, while the RSC method categorised it into two: Good and Very good. Based on the H values, the water fell into three categories: Hard, Very hard and Moderate. PI, MH, and KR only have two classes and are thus less sensitive to hydrogeochemical variations, even though they use similar parameters as RSC and H. On the contrary, RSC and H have more water suitability classes for irrigation, three and four, respectively. Moreover, their parameters fit the conditions of the study area, i.e., the influence of karst aquifers with dominant calcium and bicarbonate ions in the water.

Table 4: Water suitability analysis of the Tesih River for irrigation based on RSC, PI, MH, KR and H

Date	RSC	C	PI	C	MH	C	KR	C	H	C
17/02/2020	0.015	G	70.8	G	14.6	S	0.10	S	109.4	H
09/03/2020	0.544	G	67.1	G	46.0	S	0.12	S	147.7	H
16/03/2022	0.252	G	58.2	G	17.3	S	0.12	S	187.6	H
30/03/2020	0.718	G	66.6	G	20.7	S	0.10	S	154.2	H
13/04/2020	0.165	G	59.8	G	23.3	S	0.11	S	171.9	H
28/04/2020	0.020	G	59.1	G	25.3	S	0.18	S	189.1	H
12/05/2020	-0.175	VG	54.9	G	33.7	S	0.10	S	188.8	H
28/05/2020	-0.275	VG	56.1	G	26.4	S	0.15	S	188.9	H
06/06/2020	-0.268	VG	41.1	G	22.4	S	0.06	S	338.7	VH
22/06/2020	0.504	G	44.4	G	19.6	S	0.07	S	330.1	VH
06/07/2020	0.500	G	46.1	G	15.0	S	0.08	S	307.8	VH
20/07/2020	0.391	G	43.4	G	13.6	S	0.06	S	330.8	VH
03/08/2022	0.474	G	43.4	G	14.4	S	0.05	S	324.2	VH
18/08/2022	-0.123	VG	39.9	G	16.0	S	0.04	S	346.5	VH
31/08/2022	0.111	G	41.6	G	12.7	S	0.04	S	329.8	VH
19/09/2020	0.878	G	44.0	G	16.6	S	0.03	S	321.5	VH
26/09/2020	1.228	G	50.1	G	25.2	S	0.06	S	273.7	H
12/10/2020	0.136	G	45.1	G	20.8	S	0.02	S	268.4	H
26/10/2020	0.420	G	46.6	G	9.0	S	0.05	S	276.9	H
09/11/2020	-0.816	VG	55.6	G	45.3	S	0.13	S	145.8	M
26/11/2020	-0.82	VG	61.6	G	23.6	S	0.22	S	111.1	M
07/12/2020	-0.32	VG	65.5	G	18.4	S	0.16	S	121.1	M
21/12/2020	0.118	G	69.8	G	9.4	S	0.20	S	129.3	M
04/01/2021	-0.027	VG	73.7	G	25.5	S	0.15	S	101.4	M
19/01/2021	-0.195	VG	54.6	G	33.4	S	0.07	S	179.8	H

Notes: C (Classification), G (Good), VG (Very Good), S (Suitable for Irrigation), H (Hard), VH (Very Hard), and M (Moderate)

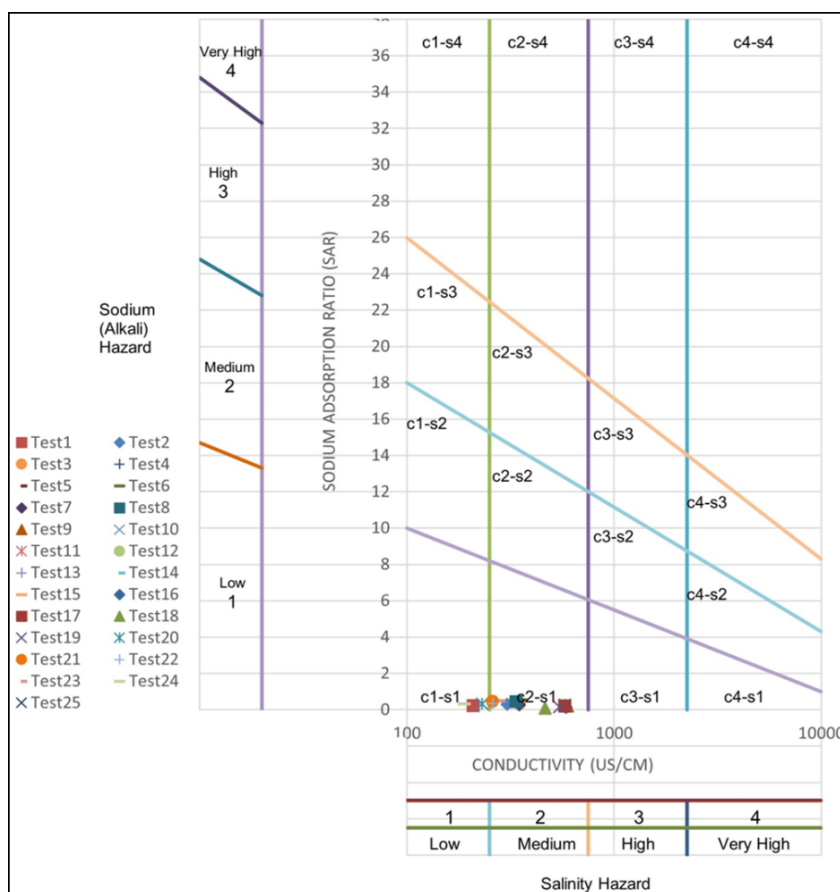


Fig. 6: USSS diagram of the Tesih River

4. Conclusion

This research confirms that seasons and geological conditions strongly influence the suitability of a water body for irrigation. During months of no substantial rain, little to no water flows from the ancient volcanic aquifer in the Tesih Watershed. This means only water from the karst aquifer feeds the Tesih River. Consequently, karstic characteristics such as calcium and bicarbonate ions dominate the water's hydrogeochemistry as a result of intensified water-rock interaction. In contrast, these ions decrease during months of rain because dilution by rainwater is the predominant process influencing their presence during the wet season. Furthermore, the river water samples are classified as Good and Very good (based on Na%, SAR, RSC and PI), Excellent to good (Wilcox diagram), Moderate to good and Good (USSL diagram), and Suitable for irrigation (MH, KR and H). From these results, it can be inferred that the influence of seasonal and geological conditions on hydrogeochemical variations does not change the classification of the water suitability for irrigation.

Hydrogeochemical analysis results should be considered in selecting the methods of water suitability assessment for irrigation. This is to find those with parameters fitting to and, thus, more sensitive to hydrogeochemical changes in the study area. In addition, methods with more classes can explain variations in water suitability better and are more practical for agricultural land and crop management.

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6. Conflict of Interest

The authors declare no conflict of interest.

7. Funding Statement

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8. Author Contributions

Ahmad Cahyadi: Conceptualization, Methodology, Data Curation, Software, Writing-Original draft preparation

Indra Agus Riyanto: Data curation, software, validation

Marseli Nabila Putri: Data curation, writing-reviewing and editing, manuscript layout

Rizka Novi Ramadhania: Data curation, writing-reviewing and editing

The authors confirm that these statements accurately represent their respective contributions to the work and that all authors have reviewed and approved the final version of the manuscript.

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مدى ملائمة المياه لري حقول الأرز في حوض مائي استوائي تسوده صخور بركانية

قديمة وحجر جبيري (إندونيسيا)

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المخلص

تعد جودة المياه المناسبة لنمو النباتات أمراً بالغ الأهمية لضمان إنتاجية عالية في مجال إنتاج الغذاء. ومع ذلك، فإن الخصائص الهيدرولوجية والجيولوجية للمنطقة تضفي عليها سمات مميزة تتطلب فهماً دقيقاً لتطبيق الممارسات الزراعية السليمة. هدفت هذه الدراسة إلى تحديد التباين الزمني في مدى ملائمة مياه نهر "تيسيه" (Tesi) لأغراض الري. ومن المتوقع أن يقدم هذا البحث لمحة عامة عن التباين الزمني في ملائمة المياه للري داخل حوض مائي تسوده صخور بركانية قديمة وتكوينات من الحجر الجيري التي شكلت مناطق كارستية. وعلاوة على ذلك، تهدف الدراسة إلى تسليط الضوء على تأثير الظروف المناخية -التي يحكمها المناخ الاستوائي وخصائص الرياح الموسمية الآسيوية- الأسترالية في موقع الدراسة- على مدى ملائمة المياه للري. الطرق المستخدمة: النسبة المئوية للصوديوم (%Na)، ونسبة امتزاز الصوديوم (SAR)، ومخطط ويلكوكس (Wilcox)، ومخطط USSSL، وعسر الماء (H)، ومخاطر المغنيسيوم (MH)، ونسبة كيلي (KR)، ومؤشر النفاذية (PI)، وكربونات الصوديوم المتبقية (RSC). وقد أظهرت التحاليل أن مياه النهر كانت جيدة (استناداً إلى %Na ومخطط USSSL وRSC)، أو جيدة جداً (وفقاً لـ SAR وPI)، أو ممتازة (وفقاً لمخطط ويلكوكس)، أو مناسبة للري (وفقاً لـ H وMH وKR). وبشكل عام، يتمتع النهر بخصائص فيزيائية وكيميائية ملائمة لدعم نمو المحاصيل دون الإضرار بخصائص التربة.

الكلمات المفتاحية:

ري حقول الأرز، الكارست (التضاريس الكارستية)، صخور بركانية قديمة، جودة المياه، الهيدرولوجيوكيمياء.

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