Analysis of Irrigation Water Quality Index and Evaluation of Land Suitability in Dryland Irrigation Systems as Efforts to Optimize Agricultural Productivity

Luthfi Inayah[1*], I Putu Gustave Suryantara Pariartha[1], Silvia Gabrina Tonyes[1]
Udayana University, Bukit Jimbaran, Badung, Indonesia[1]
E-mail address: luthfiinayah64@gmail.com

ABSTRACT

The availability and quality of irrigation water are critical factors in maintaining agricultural productivity, especially in dry areas that are prone to drought. This study analyzed irrigation water quality using the NSF-WQI and IKAPP methods as comparative approaches. Surface water samples were collected from 6 locations along the Nyuling River during the dry season (April-May 2025) to capture variations in water quality across different land uses. Physical and chemical parameters, including temperature, pH, total dissolved solids (TDS), total suspended solids (TSS), electrical conductivity (EC), sodium (Na^{+}), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^{-}), and bicarbonate (HCO_3^{-}), TDS, BOD, COD, nitrite (N), lead (Pb), metal, and SAR. The IKAPP value ranged from 23.69, indicating low vulnerability to pollution, while the NSF-WQI results ranged from 69.96 to 79.78, indicating moderate to good water quality and more consistency in assessing water suitability for irrigation compared to IKAPP. Integration was also carried out with soil permeability data to facilitate the analysis and evaluation of land using ArcGIS to integrate water quality index results with land characteristics. The integration of water quality and land evaluation provides a clear spatial representation of areas suitable for the development of crop types in dryland agriculture. This approach supports sustainable agricultural planning in identifying and evaluating to optimize land use and water resource allocation in dryland agriculture or similar areas.

Keywords: crop suitability, dryland agriculture, irrigation water quality, IKAPP method, NSF-WQI method

1. INTRODUCTION

Agricultural productivity in dryland areas is increasingly threatened by limited and deteriorating irrigation water quality [1]. In Abang sub-district this challenge is exacerbated by the dominance of sloping land, erratic rainfall, and inadequate irrigation infrastructure. Despite the region's volcanic soil structure and *perennial* surface water sources such as Tukad Nyuling, land productivity remains suboptimal due to declining irrigation water quality, salinity build-up, and poor land management practices [2].

Surface water contamination due to agricultural runoff, sediment transport, and unregulated domestic discharges has led to significant ecological stress and reduced crop yields [3]. These conditions demand an integrated evaluation approach that considers not only the physical and chemical characteristics of irrigation water but also the compatibility between water, soil, and crop type [4]. Previous research has highlighted the importance of matching water quality with soil permeability and crop tolerance to optimize land use [5], [6].

Three villages near Tukad Nyuling, namely Abang Village, Ababi Village, and Tiyingtali Village, were the locations of this study. Water quality in Abang Village is classified as moderate to low, while salinity and poor soil permeability are problems in some areas. Ababi Village's low water quality makes it ideal for all types of horticultural plantations. Meanwhile, Tiyingtali Village has relatively steep terrain and its water quality varies in the low category, requiring better conservation management and irrigation systems. The uniqueness of each location emphasizes the need for a comprehensive strategy that considers land use, soil conditions and water quality to plan sustainable agriculture.

Unlike previous studies in Indonesia, which generally use only one index in a study, such as IKAPP for pollution vulnerability analysis or NSF-WQI for groundwater quality analysis, this study integrates two approaches NSF-WQI for irrigation water quality and IKAPP for surface water vulnerability in its application to dry agricultural land. This integration allows for more comprehensive recommendations, as it combines current water quality analysis with long-term vulnerability to pollutant contamination.

2. THEORY AND METHODS

2.1 Theory

Assessment of water quality for irrigation requires an understanding of the relationship between water quality, soil characteristics and crop tolerance. In this study, the NSF-WQI method was used as the main reference framework, which integrates EC, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^- and SAR parameters into one composite index value [7]. These parameters play an important role in evaluating the risk of salinity, soil permeability, and potential toxicity to plants, and the results are able to categorize irrigation water from excellent to unusable.

This method is supported by the concept of agroecological zoning-oriented land assessment, which links water suitability to soil conditions [8]. When compared to IKAPP, the NSF-WQI method is considered more responsive to differences in water quality and better suited to the agricultural situation in the study site [9], as corroborated by several previous studies. A detailed explanation of the selection of this method will be outlined in the discussion section.

2.2 Method

This research was conducted in three irrigation areas within Abang Sub-district, namely DI Pajegan (Tiyingtali Village), DI Andong (Abang Village), and DI Ababi VII (Ababi Village). The research method applied was a quantitative descriptive design, integrating laboratory analysis, field observation and spatial mapping. Six locations were taken as sample points along Tukad Nyuling and irrigation inlets, which were chosen to represent variations in topography and land use. The limited number of samples at only six points is acknowledged to affect the representativeness of the results, but the selection of locations took into account topographical variations, suitability for evaluation, and land use around the area.

Water quality was analyzed using NSF-WQI: pH, Na^+, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-, SAR. While IKAPP: water quality, rainfall index, population density, land use/vegetation cover, hydrogeomorphic index. Soil analysis was conducted to determine permeability, and crop suitability was identified based on IWQI guidelines, which combine water quality data with soil characteristics and crop tolerance to salinity. Spatial distribution maps were created using ArcGIS 10.4.1.

2.2.1. Index of Surface Water Vulnerability (IKAPP) Method

The Index of Surface Water Vulnerability (IKAPP) method was applied to assess the vulnerability of surface water resources to pollution in the study area. The IKAPP model integrates five main indicators: water quality index (I_{KA}) (e.g. TDS, BOD, COD, nitrite, and heavy metals), rainfall index (I_{CH}), population index (I_{KP}), land use and vegetation cover index (I_{PLV}), and river hydrogeometry index (I_{HS}) [10]. The calculations for each indicator comprising the overall IKAPP are as follows:

I_{KA} = 0,12qi-t + 0,15qi-TDS + 0,19qi-BOD + 0,13qi-COD + 0,07qi-P + 0,08qi-N + 0,09qi-pH + 0,09qi-TSS + 0,08qi-Pb
qi-t = class value based on water temperature classification results
qi-tds = class value based on water TDS classification results
qi-bod = class value based on water BOD classification results
qi-cod = class value based on water COD classification results
qi-P = class value based on water phosphate classification results
qi-N = class value based on water nitrite classification results
qi-pH = class value based on water pH classification results
qi-tss = class value based on water TSS classification results
qi-Pb = class value based on water lead classification results

I_{CH} = 0,54qi-kh + 0,46qi-bb
qi-kh = class value based on classification of regional average rainfall
qi-bb = class value based on classification of wet months

I_{KP} = 0,5qi-kp + 0,5qi-pp
qi-kp = class value based on population classification
qi-pp = class value based on population growth rate classification

I_{PLV} = 0,55qi-PL+ 0,45qi-TV
qi-pl = class value based on land use classification
qi-tv = class value based on land vegetation cover classification

I_{HS} = 0,31qi-Q + 0,21qi-S + 0,24qi-L + 0,24qi-D
qi-Q = class value based on channel discharge classification
qi-S = class value based on sediment load classification
qi-L = class value based on channel width classification
qi-D = class value based on channel depth classification

After obtaining the values from the constituent indicators, the IKAPP value can be calculated to determine the vulnerability threshold for irrigation water value.

$$IKAPP = 0{,}29I_{KA}+0{,}23I_{KP}+0{,}14I_{CH}+0{,}20I_{PLV}+0{,}14I_{HS} \quad (1)$$

I_{KA} = water quality index
I_{PLV} = land use and vegetation cover index
I_{CH} = rainfall index
I_{HS} = river hydrogeometric index
I_{KP} = population density index

The results of the IKAPP calculation are classified into vulnerability categories to interpret the level of pollution risk affecting irrigation water resources.

2.2.2. *National Sanitation Foundation -Water Quality Index* Method

NSF-WQI is a method used to determine the water quality status of several water quality parameters, namely physical parameters in the form of temperature, turbidity and dissolved solids, and chemical parameters in the form of DHL, pH concentration, Na^{+}, Ca^{2+}, Mg^{2+}, Cl^{-}, HCO_3^{-}, and corrected SAR [11].

SAR Parameter

Sodium Adsorption Ratio (SAR) is used to assess the potential of irrigation water to cause soil sodicity, which can reduce water infiltration. SAR is calculated using the following formula:

$$SAR_{adj} = \frac{Na}{\sqrt{\frac{Ca_{eq}+Mg}{2}}} \quad (2)$$

Where:
SAR_{adj} = adjusted sodium adsorption ratio $(mEq/l)^{1/2}$
Na^{+}, dan Mg^{2+} = ion concentration by milliequivalent per liter (mEq / l)
Ca_{eq} = equilibrium calcium concentration (mEq / l)

With concentrations in units of meq/L. High SAR values can cause the soil to become dispersive, thereby reducing crop productivity.

Parameter Weighting (wi)

Each parameter is assigned a weighting factor (wi) as shown in Table 1 based on the parameters contained in the water to determine the overall NSF-WQI calculation.

Table 1. Weights for wi values

Parameter	Weight (wi)
Electrical Conductivity (DHL)	0.211
Sodium (Na^{+})	0.204
Bicarbonate (HCO_3-)	0.202
Chloride (Cl-)	0.194
Sodium Adsorption Ratio (SAR)	0.189

Final NSF-WQI Calculation

The NSF-WQI is calculated using a weighted sum of the scores of each parameter:

$$\text{NSF-WQI} = \sum_{i=1}^{n} qi \times wi \quad (3)$$

Where:
qi = quality score for parameter i
wi = weight for parameteri
n = number of parameters (n = 5)

2.2.3. Spatial Distribution Mapping of the Irrigation Water Quality Index

After the field survey and acquisition of the necessary data, spatial mapping was conducted to produce a distribution map of the Irrigation Water Quality Index. Spatial analysis of sampling points and flow paths was conducted using ArcGIS version 10.4.1 to ensure accurate visualization and interpretation of irrigation water quality across the study area [12].

In addition, the water quality index was matched with field soil data (permeability and texture classes) to evaluate irrigation suitability. Soil permeability was classified based on the infiltration test results:

2.2.4. Determination Table

Plant suitability classification is based on the integration of NSF-WQI values and soil permeability, with reference to characteristic tables based on IWQI values such as Table 2. Table 2 shows the correlation between the calculated irrigation water quality index and physical properties of the soil (especially permeability) and the recommended plant types [13]. In this study, the method chosen was NSF-WQI, which was determined based on rational analysis and correlation of results and land tolerance to salinity and water retention capacity.

Table 2. Classification of water, soil, and plant quality index characteristics

IWQI	Water use restrictions	Recommendations	
		Soil	Plants
85 - 100	**None restriction (NR)**	Can be used on land at low risk of salinity, except on soils with low permeability	Suitable for most crops without risk of damage

IWQI	Water use restrictions	Recommendations	
		Soil	Plants
70 - 85	**Low restriction (LR)**	Suitable for light textured or medium permeability soils. Salt leaching recommended	Avoid salt sensitive crops
55 - 70	**Medium restriction (MR)**	Can still be used on soils with medium to high permeability	Suitable for crops with salt tolerance
40 - 55	**High restriction (HR)**	Caution is needed on soils with high permeability or dense layers. Irrigation scheduling should be adjusted especially if DHL > 2000 µS/cm and SAR value > 7	Used only for moderate to high salt tolerant crops and needs control of Na^+, Cl^-, HCO_3^- in water
0 - 40	**Inappropriate/Hazardous (SR)**	Not recommended for routine irrigation, limited use and only under certain conditions (water with high salt content and SAR, use of lime)	Only highly salt-tolerant crops can grow, unless the Na, Cl, and HCO_3 levels in the water are very low

3. RESULTS AND DISCUSSION

The research results consist of water quality and soil permeability data, obtained through direct field measurements and laboratory testing. These data were then converted based on NSF-WQI or IKAPP parameter analysis. The measurement and testing results were then analyzed in the context of the IWQI model, water suitability for specific soil types and crops, and spatial distribution mapping, to come up with appropriate recommendations and solutions to the identified problems [9].

3.1 Results

Table 3 presents the results of direct measurements (physical parameter measurements) in the field of irrigation water at the channel inlet using a pH meter and EC meter.

Table 3. Results of measurement of water physical parameters

Sample code	Parameter						
	Temp	TDS	TSS	DHL	pH	Color	Odor
T.01	27.00	181.0	5.00	251	6.1	No	No
T.02	28.00	214.5	4.80	264	6.8	No	No
T.03	27.60	253.2	26.60	698	7.2	No	No
T.04	28.60	212.0	31.90	234	7.1	No	No
T.05	27.60	265.6	24.10	362	6.6	No	No
T.06	26.50	257.2	21.60	256	6.7	No	No

Tables 4 to 6 show the results of measurements taken through laboratory tests. Specifically, Tables 3 and 4 contain test data used for calculations using the IKAPP method, while Table 5 contains test data used for calculations based on the NSF-WQI method.

Table 4. Measurement results of water chemistry parameters

Sample code	Parameter				
	BOD (mg/l)	COD (mg/l)	PO_4 (mg/l)	Nitrite (mg/l)	Pb (mg/l)
T.01	4.5	20.73	0.14	0.017	0.050
T.02	5.4	15.2	0.28	0.012	0.017
T.03	5.1	15.48	0.23	0.031	0.024
T.04	3.9			0.026	
T.05					
T.06					

Table 5. Measurement results of water chemical parameters

Sample code	Parameter					
	Ca^{+2} (mg/l)	Mg^{+2} (mg/l)	SO_4-^{2} (mg/l)	Na^+ (mg/l)	Cl- (mg/l	HCO-$_3$ (mg/l)
T.01	9.25	6.66	27.27	16.25	17.89	94.06
T.02	9.15	6.56	35.85	15.60	17.35	95.73
T.03	17.49	25.80	76.18	17.90	40.78	324.50
T.04	12.88	7.33	43.22	14.30	44.74	309.80
T.05	14.99	14.67	46.70	16.20	24.44	320.20
T.06	9.14	6.59	35.89	15.20	20.37	101.90

In addition to water quality test data, soil permeability data such as Table 6 based on laboratory testing is also required for use in evaluating the suitability of agricultural land.

Table 6. Soil permeability measurement results

Sample code	Permeability (cm/hour)	Permeability classification	Soil texture	Structure shape
TS.01	1.99	Very slow	Sandy loam	Subangular blocky
TS.02	125.92	Very rapid	Loam	Angular blocky
TS.03	129.90	Very rapid	Sandy clay loam	Blocky subangular

3.2 Discussion

In analyzing the condition of irrigation water quality against any contaminants present, this study used a structured evaluation of irrigation water quality and its spatial suitability for agriculture. While two analytical frameworks were explored namely NSF-WQI *(National Sanitation Foundation Water Quality Index)* and IKAPP (Surface Water Vulnerability Index) through discussion in the calculation formula as follows:

3.2.1. Surface Water Vulnerability Index (IKAPP)

Tables 7 to 11 are used to determine the results of the parameter index that constitutes the vulnerability value of the IKAPP method through the results of the polynomial regression model equation for all study locations. Then, in Table 12, the overall tabulation results of the parameters that constitute the surface water vulnerability value are obtained.

Table 7. Calculation of surface water quality index parameters

Indicator	Weight	Formula	Actual data X average	Sub-indicator index	Index
Temperature	0.12	y = -0.4747x2 + 16.154x	27.54	84.84	10.18
TDS	0.15	y = -0.0021x2 + 0.8013x + 24.806	230.59	97.92	14.69
BOD	0.19	$y = 19.821x^2 - 196.57x + 544.67$	4.73	58.39	11.09
COD	0.13	$y = -0.4306x^2 + 11.82x$	17.14	76.10	9.89
Total phosphate	0.07	$y = 1587.3x^2 - 809.52x + 182.22$	0.22	81.34	5.69
NO_2 as N	0.07	$y = 2E\text{-}09x^2 - 633.48x + 98.62$	0.022	85.00	5.87
pH	0.12	$y = -18.49x^2 + 252.79x - 771.25$	6.783	92.72	10.85
TSS	0.08	$y = 0.0091x^2 - 1.4856x + 107.07$	19.00	82.13	6.16
Lead (Pb)	0.07	$y = -22750x^2 + 925.93x + 90.849$	0.030	98.02	7.25
	1.00	Water quality index			81.68

Table 8. Rainfall index parameter calculation

Indicator	Weight	Formula	Actual data x average	Sub-indicator index	Index
Average rain	0.54	y = 9E-06x2 + 0.0067x + 11.955	1868.47	55.89	30.18
Wet month	0.46	y = -8.75x + 111.36	4.00	75.78	34.86
	1.00	Rainfall indeks			65.04

Table 9. Calculation of population index parameters

Indicator	Weight	Formula	Actual Data x Average	Sub-indicator index	Index
Density	0.50	y = 1.6115x	44.00	70.90	35.45
Growth rate	0.50	$y = -1.3065x^2 - 35.359x + 100.66$	0.64	77.37	38.68
	1.00	Population index			74.14

Table 10. Calculation of land use and vegetation cover index parameters

Indicator	Weight	Formula	Actual data x average	Sub-indicator index	Index
Land use	0.55	$y = -0.0002x^2 + 0.1266x + 40.956$	1.00	52.04	28.62
Vegetation	0.45	$y = -0.0066x^2 + 1.6217x$	7.16	73.57	33.11
	1.00	Land use and vegetation cover index			61.73

Table 11. Calculation of river hydrogeometric index parameters

Indicator	Weight	Formula	Actual data x average	Sub-indicator index	Index
Discharge	0.31	$y = -4.3528x^2 + 60.134x - 136.84$	6.56	70.31	21.80
Sediment	0.21	$y = 6E\text{-}08x^2 - 0.0045x + 90.563$	11.11	57.67	12.11
Width	0.24	-	12.60	50.00	12.00
Depth	0.24	-	8.50	90.00	21.60

Indicator	Weight	Formula	Actual data x average	Sub-indicator index	Index
	1.00	River hydrogeometric index			67.51

Table 12. Composite calculation of surface water vulnerability index to pollution

Parameter component	Sub-index	Weight	Index
Water quality	81.68	0.29	23.69
Rainfall	65.04	0.14	9.11
Population	74.14	0.23	17.05
Land use and vegetation cover	61.73	0.20	12.35
River hydrogeomics	67.51	0.14	9.45
IKAPP		1.00	71.64

The Nyuling sub-watershed is categorized as relatively vulnerable based on an IKAPP score of 71.64, indicating a high sensitivity to pollution, especially for areas with similar watershed characteristics. Water quality has the greatest impact on the resulting index value, followed by population, river hydrogeometry, rainfall, and then land use and vegetation cover.

Meanwhile, population growth has driven an annual increase in land use, which has gradually reduced vegetation cover, according to BPS statistics. Spatial variations in water quality reflect the influence of land use and surface runoff, with areas with minimal vegetation tending to have higher TSS and BOD values. However, the vulnerability level score of 23.69 for agricultural land water quality is still considered quite good when evaluated based on the values of each indicator.

3.2.2. National Sanitation Foundation -Water Quality Index Method

Based on the test results from the laboratory, calculations were performed using the NSF-WQI model in Table 13, adjusted according to formula 3 in the methods section.

Table 13. NSF-WQI model water quality index value

Location	pH	DHL	Ca^{+2}	Mg^{+2}	SO_4^{-2}	SAR	Na^+	Cl-	HCO_3^-	Results
T.01	6.1	251	0.46	0.55	0.57	0.69	0.71	0.50	1.54	79.78
T.02	6.8	264	0.46	0.54	0.75	0.83	0.68	0.49	1.57	79.62
T.03	7.2	698	0.87	2.12	1.59	0.99	0.78	1.15	5.32	69.96
T.04	7.1	234	0.64	0.60	0.90	0.85	0.62	0.98	5.08	73.74
T.05	6.6	362	0.75	1.21	0.97	0.76	0.70	0.16	5.25	72.86
T.06	6.7	256	0.46	0.54	0.75	0.81	0.66	0.58	1.67	79.04

Water quality index (qi) values ranged from 69.96-79.78, classifying the water as low to moderate use limit. Slightly alkaline pH levels indicate higher bicarbonate (HCO_3-) content, with indirect effects from magnesium and calcium, but still within standards. Sites T.01, T.02, T.04, T.05, and T.06 are below the low use limit, while T.03 is moderate, mainly affected by electrical conductivity, and bicarbonate. Elevated parameters lower the NSF-WQI score, suggesting domestic or agricultural pollution sources. Higher mineral sodium content at some sites indicates potential water hardness, shaped by the distance between sampling points, soil properties, and weather during sampling [14].

There are several findings from the results obtained, namely the high HCO_3^- and EC values at locations T.03 and T.05, which are thought to be related to volcanic rock weathering and agricultural runoff, which is consistent with the topography and characteristics of the study area.

In dry land systems, intensive evaporation can increase the concentration of these ions, which has the potential to affect the suitability of water for sensitive plants.

3.2.3. Correlation and Rationality Analysis

A correlation and rationality analysis between the Index of Surface Water Susceptibility (IKAPP) and NSF-WQI was conducted to evaluate how closely related these methods are and their relevance in representing surface water quality in the study area. This analysis aims to provide scientific justification for linking or contrasting the use of the two indices in data- and risk-based water resources management [15].

Correlation coefficient and standard deviation calculations were conducted at one point of the study site to see the stability of each method's values, as follows:

Example of IKAPP calculation:

Mean qi-sub. index = 70.02

Mean WQI index (weight) = 71.64

$$Sd = \sqrt{\frac{\sum_{i=1}^{n}(Xi - Xr)^2}{n}}$$

= 51.162

$$Cv = \frac{Sd}{Xr} \times 100\%$$

= 71.415%

NSF-WQI calculation example:

Average qi-sub. index = 80.08

Average WQI index (weight) = 79.78

$$Sd = \sqrt{\frac{\sum_{i=1}^{n}(Xi - Xr)^2}{n}}$$

= 38.352

$$Cv = \frac{Sd}{Xr} \times 100\%$$

= 48.070%

NSF-WQI is more suitable for rapid evaluation of water quality, while IKAPP is more efficient for long-term planning of watershed ecosystems. Comparative analysis revealed that NSF-WQI is more suitable to the local situation and data availability. The small values of standard deviation and coefficient of variation indicate that NSF-WQI is the most consistent and reliable method for this study area.

3.2.4. Suitability of Water Quality Index Values for Irrigation to Soils and Crops

The suitability of plant types according to the analysis in Table 14 is adjusted to regional characteristics and assessed based on the economic value generated to increase crop yields, farmer welfare, and the sustainability of the agricultural sector. Land management is recommended based on threshold limits, regional characteristics, soil texture, and root medium type to meet the needs of specific commodities [16].

Table 14. Compatibility of water quality index values for irrigation with soils and plants

Location	WQI Value	Existing Condition		Analysis Recommendation	
		Soil	Plants	Soil	Plant
T.01	79.78	Very rapid	Rice, corn, onion, petsai, papaya, banana	Very high permeability, on non-steep slopes added biochar with	Recommended replacement of petsai plants with plants that are not salt sensitive and according to the

Tiyingtali				a rotary system & steep slopes left to be naturally vegetative closed	characteristics of the region such as mustard greens and added coconut plants, long beans
T.02 Tiyingtali	79.62	Very rapid	Rice, corn, shallots, petsai, papaya, banana	Permeability is very high, on slopes that are not steep, biochar is added with a rotary system and steep slopes are left to be naturally vegetative closed.	Recommended replacement of petsai plants with plants that are not salt sensitive and in accordance with the characteristics of the region such as mustard greens and added coconut plants, long beans
T.03 Abang	69.96	Very rapid	Rice, corn, potatoes, yam, peanuts, chili peppers, large chili peppers, shallots, durian	–	Recommended to plant crops that have sesnsitifitas to salt and in accordance with the characteristics of the region.
T.04 Abang	73.74	Very rapid	Rice, corn, potatoes, peanuts, chili peppers, large chili peppers, shallots, yam, durian	High permeability, on non steep slopes added biochar with rotary system & steep slopes left to natural vegetative covered	Recommended to replace shallots and durian with crops that are not salt sensitive and in accordance with the characteristics of the region such as eggplant, cucumber, papaya, muskin melon, jackfruit, pineapple
T.05 Ababi	72.86	Very slow	Rice, corn, potato, yam, onion, papaya, jackfruit, durian	Soil permeability is rather slow, soil loosening and guludan technique can be done thoroughly and sand, manure, or plant biomass can be added.	Recommended to replace shallots and papaya with crops that are not salt sensitive and suitable for the characteristics of the region such as coconut, coffee, cacao, banana, salak, jackfruit, durian.
T.06 Ababi	79.04	Very slow	Rice, corn, shallots, yam, papaya, jackfruit, durian	Soil permeability is rather slow, soil loosening and guludan technique can be done thoroughly and sand, manure, or plant biomass can be added.	Recommended to replace shallots and papaya with crops that are not salt sensitive and suitable for the characteristics of the region such as coconut, coffee, cacao, banana, salak, jackfruit, durian.

The high EC and bicarbonate levels, particularly at sites T.03 and T.05, reflect the influence of volcanic parent material and dry-season hydrological conditions. Limited rainfall and high evapotranspiration concentrate dissolved minerals, while weathering of volcanic deposits enriches bicarbonate. Sodium enrichment may also come from domestic discharges. In areas with rapid permeability (T.01 - T.04), salts tend to leach quickly but can cause nutrient loss, whereas in slow-permeability zones (T.05 - T.06), salt buildup in the root zone may occur. These conditions require site-specific strategies such as periodic leaching, organic amendments, and the selection of salt-tolerant crops to maintain soil productivity.

The IWQI measurements show differences in water quality, where T.01 (79.78) and T.05 (72.86) are low limit, while T.03 (69.96) falls into the medium limit category. Overall, the water sources for irrigation in Abang facilitate agricultural activities, but the types of crops grown need to be adjusted accordingly. The soils in T.01 and T.03 have very high permeability >120 cm/h, while T.05 has low permeability 1.99 cm/h, which poses different challenges in terms of the suitability of water and crops. Some crops, such as rice and shallots, do not thrive well in this situation. T.03 is more suitable for the cultivation of salt-tolerant crops, such as corn and chili, while T.05 is more suitable for moisture-demanding crops, such as yam and durian. The decline in yields over the past five years is attributed to the suitability of water quality, soil permeability and the type of crops grown.

4. CONCLUSIONS

Water quality for irrigation in Abang District generally ranges from moderate to good, although some areas face challenges related to high salinity and varying soil permeability. The NSF-WQI method has proven to be more reliable for local irrigation evaluation and can be adopted as a standard monitoring tool in dry farming systems in Bali, particularly in the Abang District. The classification and analysis conducted on water quality and soil characteristics enable appropriate recommendations to support sustainable agricultural production in arid areas. Routine monitoring is necessary to capture seasonal variations in water quality.

The integration of water quality indices and land suitability analysis shows that about 60% of the study area is suitable for moderately salt-tolerant crops such as corn, papaya, eggplant, cucumber, jackfruit, salak, banana, chili, as well as new commodities such as coffee, cocoa, melon, durian, pineapple, and coconut. Special land management is required in areas with high SAR values. The NSF-WQI method can serve as a standard tool for irrigation monitoring in Bali's dryland systems, and the results should be integrated into local agricultural policies and water resource management plans to support long-term adaptation to climate change and land use.

REFERENCES

[1] P. M. Chimwamurombe And P. N. Mataranyika, “Factors Influencing Dryland Agricultural Productivity,” *J. Arid Environ.*, Vol. 189, P. 104489, Jun. 2021, doi: 10.1016/j.jaridenv.2021.104489.

[2] J. A. J. P. Sitepu, N. L. Watiniasih, And A. P. W. K. Dewi, “Analisis Kualitas Air Di Sungai Telagawaja Kabupaten Karangasem, Bali,” *Metamorf. J. Biol. Sci.*, Vol. 10, No. 1, P. 150, Apr. 2023, doi: 10.24843/metamorfosa.2023.v10.i01.p16.

[3] J. M. Sagasta, S. M. Zadeh, And H. Turral, “Water Pollution from Agriculture: A Global Review - Executive Summary,” *Food Agric. Organ. U. N. Rome 2017 Int. Water Manag. Inst. Behalf Water Land Ecosyst. Res. Program Colombo 2017*.

[4] N. Oktaviani and G. Wardana, “Pengaruh Tingkat Pendidikan Dan Upah Terhadap Kesempatan Kerja Dan Kemiskinan di Kabupaten/Kota Provinsi Bali”.

[5] M. Qadir, Th. M. Boers, S. Schubert, A. Ghafoor, And G. Murtaza, "Agricultural Water Management in Water-Starved Countries: Challenges and Opportunities," *Agric. Water Manag.*, Vol. 62, No. 3, Pp. 165–185, Oct. 2003, doi: 10.1016/s0378-3774(03)00146-x.

[6] J. Bartram, R. Ballance, United Nations, And World Health Organization, Eds., *Water Quality Monitoring: A Practical Guide to The Design and Implementation Of Freshwater Quality Studies And Monitoring Programmes*, 1st Ed. London; New York: E & Fn Spon, 1996.

[7] A. C. M. Meireles, E. M. D. Andrade, L. C. G. Chaves, H. Frischkorn, And L. A. Crisostomo, "A New Proposal of The Classification of Irrigation Water," *Rev. Ciênc. Agronômica*, Vol. 41, No. 3, Pp. 349–357, Sep. 2010, doi: 10.1590/s1806-66902010000300005.

[8] V. V. Tentua, H. Salampessy, And J. P. Haumahu, "Kesesuaian Lahan Komoditas Hortikultura di Desa Hative Besar Kecamatan Teluk Ambon," *J. Budid. Pertan.*, Vol. 13, No. 1, P. 9, Jul. 2017, doi: 10.30598/jbdp.2017.13.1.9.

[9] M. D. P. Gupta, "Studi Penentuan Status Mutu Air Menggunakan Metode Indeks Pencemaran Dan Wqi Di Tukad Badung, Denpasar," *J. Tek. Pengair.*, Vol. 11, No. 2, Pp. 83–93, Nov. 2020, doi: 10.21776/ub.pengairan.2020.011.02.02.

[10] H. Poedjiastoeti, S. Sudarmadji, S. Sunarto, And S. Suprayogi, "Penilaian Kerentanan Air Permukaan Terhadap Pencemaran di Sub DAS Garang Hilir Berbasis Multi-Indeks," *J. Wil. Dan Lingkung.*, Vol. 5, No. 3, P. 168, Dec. 2017, doi: 10.14710/jwl.5.3.168-180.

[11] T. Yan, S.-L. Shen, And A. Zhou, "Indices and Models of Surface Water Quality Assessment: Review and Perspectives," *Environ. Pollut.*, Vol. 308, P. 119611, Sep. 2022, doi: 10.1016/j.envpol.2022.119611.

[12] L. Inayah, H. Siswoyo, And J. S. Fidari, "Pemetaan Nilai Indeks Kualitas Air Tanah Untuk Irigasi di Kecamatan Negara Kabupaten Jembrana Provinsi Bali," *J. Teknol. Dan Rekayasa Sumber Daya Air*, Vol. 2, No. 2, P. 91, Mar. 2022, doi: 10.21776/ub.jtresda.2022.002.02.07.

[13] I. García-Garizábal, J. Causapé, And D. Merchán, "Evaluation of Alternatives for Flood Irrigation and Water Usage in Spain Under Mediterranean Climate," *Catena*, Vol. 155, Pp. 127–134, Aug. 2017, doi: 10.1016/j.catena.2017.02.019.

[14] A. Aprila Permatasari and S. Vienastra, "Kelayakan Air Tanah Untuk Irigasi Pertanian Menggunakan Sodium Arbsoption Ratio (SAR)," *Comserva Indones. J. Community Serv. Dev.*, Vol. 2, No. 5, Pp. 497–505, Sep. 2022, doi: 10.59141/comserva.v2i5.605.

[15] Md. G. Uddin, S. Nash, And A. I. Olbert, "A Review of Water Quality Index Models and Their Use for Assessing Surface Water Quality," *Ecol. Indic.*, Vol. 122, P. 107218, Mar. 2021, doi: 10.1016/j.ecolind.2020.107218.

[16] "Technical Options for Sustainable Land and Water Management," In *The State of The World's Land and Water Resources for Food and Agriculture*, 0 Ed., Routledge, 2020, Pp. 163–202. doi: 10.4324/9780203142837-17.