Evaluation of surface water for agricultural irrigation in Lobalain District, Rote Ndao Regency, East Nusa Tenggara Province, Indonesia

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Abstract. The average rice productivity of the Rote Ndao Regency is still below the national rice productivity. The cropping pattern's lack of management and limited water sources can only be planted once a year. This study aims to determine the availability and quality of surface water used for irrigation with the existing rice-corn-fallow cropping pattern. The research was carried out by measuring discharge in the field, surveying the types and cropping patterns, irrigation area research, surface water quality analysis, and hydrological analysis. The results showed that the need for irrigation water for agriculture in the study area with the current cropping pattern was 0.84 l/s/ha. Therefore, the existing irrigation area of ±3,762.00 Ha requires a water discharge of ±3.159 m³/second. The availability of surface water in the Lobalain District is low, with a discharge of ±1.598 m³/second. Surface water quality shows the percentage of sodium (Na%) dominated by excellent to permissible class, and the sodium adsorption ratio (SAR) excellent. The existing resource of surface water could not support agricultural irrigation. Therefore, it is necessary to find an alternative water source such as groundwater.

Keywords: Agricultural Irrigation, Surface Water, Water Quantity, Water Quality.

1. Introduction
The need for irrigation water is determined by the factors of the planting area, the cropping patterns used, and the climate that influences the irrigation area. However, based on the existing land potential, it is still possible to develop irrigation areas in the Noelmina river basin if supported by irrigation network facilities and infrastructure. For example, the irrigation area in the Noelmina river basin in 2013 was 10,519 Ha consisting of Kupang Regency ± 4,065 Ha, South Middle East Regency ± 3,659 Ha, Kupang City ± 160 Ha, Saibu Raiju Regency ± 378 Ha, and Rote Ndao Regency ± 2,257 Ha with a total need of irrigation water of 10.52 m³/second or 331.12 million m³ [1].

Rote Ndao Regency is a rice barn area in East Nusa Tenggara Province with an irrigated area of 19,691.55 Ha or 15.38% of the area of Rote Ndao Regency [2]. Based on the Central Bureau of Statistics data, the average rice productivity of Rote Ndao Regency in 2017 was 5.00 tons/ha, which is still below
the national rice productivity of 5.70 tons/Ha [3]. One of the causes of the low productivity of rice is the lack of water resources for agricultural irrigation and water quality in several locations that do not meet the quality standards of water quality standards for agricultural irrigation, especially in the Lobalain District. Lobalain District has an irrigation area of ± 3,762.00 Ha or 25.82% of the area of Lobalain District. Due to a lack of management and limited water sources that do not flow throughout the year, the average cropping pattern can only be planted yearly.

The main problem in Lobalain District is surface water availability that can be used for agricultural irrigation. Therefore, this study aims to determine the quantity and quality of the surface water in the Lobalain District. In addition, the need for agricultural irrigation also will be a study based on the existing condition.

2. Materials and Methods

Lobalain District is one of the Districts in the Rote Regency, covering 145.71 Km², divided into 15 villages as shown in Figure 1. Irrigation water needs data in Lobalain District were obtained from the PUPR office of the Rote Ndao Regency, while the rainfall and climatological data come from the Meteorology, Climatology, and Geophysics Agency David Constantijn Saudale, Rote Island [4]. Thirty-one water samples were taken from the field and tested as shown in Figure 1, including \( \text{Na}^+, \text{K}^+, \text{Ca}^{2+}, \text{Mg}^{2+}, \text{NH}_3, \text{Cl}^-, \text{SO}_4, \text{NO}_3, \text{HCO}_3, \) and B at the Yogyakarta Environmental Health Engineering Center, according to the Indonesian National Standard (SNI). Meanwhile, temperature, pH, EC, and TDS were measured directly in the field with a portable pH meter from Hannameter. In addition, rain data daily, daily air temperature, daily humidity, daily sunshine, and daily wind speed from 2014 to 2020 are used to calculate evapotranspiration in the field.

![Figure 1. Map of research locations and surface water sampling points](image)

The data analysis was divided into several phases, including evapotranspiration analysis (ET\(_o\)), daily rainfall and effective rainfall analysis (R\(_e\)), irrigation water demand analysis (NFR), and water quality analysis.
Evapotranspiration analysis (ET\textsubscript{o}) is needed to determine the amount of plant evapotranspiration to calculate irrigation water needs [5]. The potential evapotranspiration (ET\textsubscript{o}) was calculated using the Modified Penman Method [6], as shown in Equation 1.

\[
ET\textsubscript{o} = c \times (W \times Rn + (1 - W) \times f_u \times (ea - ed))
\] (1)

With:
- ET\textsubscript{o} = daily potential evapotranspiration,
- c = correction factor,
- W = a factor related to temperature,
- Rn = net wave radiation (mm/day),
- f = a factor that depends on the wind speed (km/day),
- ea = value of saturated vapor pressure (m bar),
- ed = value of the actual water vapor pressure (m bar).

When calculating the effective rainfall of plants using the Gumbel Method, the first step is to analyze the daily rainfall based on rainfall data obtained with a specific return period, then calculate the effective rainfall (R\textsubscript{e}) and the effective rainfall of plants (PUPR 2010). For example, the effective monthly rainfall is taken from the analysis of effective rainfall for rice crops based on 70% of the rainfall. For corn crops, the effective monthly rainfall is taken based on 50% of the rainfall shown in Equation 2.

\[
R\textsubscript{e} \text{ rice} = 0.7 \times \frac{1}{15} \times R\text{ (80)} \quad \text{and} \quad R\text{e} \text{ palawija} = 0.5 \times \frac{1}{15} \times R\text{ (80)}
\] (2)

With:
- R\text{e} \text{ rice} = effective rainfall of rice plants (mm/day)
- R\text{e} \text{ palawija} = effective rainfall of secondary crops (mm/day)
- R\text{80} = average minimum rainfall monthly with possibility fulfilled 80% (mm/15 days).

The need for clean water in the fields (NFR) is influenced by factors such as land preparation, consumptive use, inundation, percolation, and infiltration, taking into account effective rainfall (R\textsubscript{e}) (PUPR 2010). After the value of evapotranspiration (ET\textsubscript{o}) and effective rainfall of plants (R\textsubscript{e} of plants) is known, the need for irrigation water can be obtained by equation 3.

\[
NFR = ET\textsubscript{c} + P + WLR - Re
\] (3)

With:
- NFR = Netto Field Water Requirement, the need for clean water in the fields (mm/day)
- ET\textsubscript{c} = Plant evaporation (mm/day)
- P = Percolation (mm/day)
- WLR = Replace water layer (mm/day)
- Re = Effective rainfall (mm/day)

The water requirement during land preparation was calculated using the formula developed by Van De Goor and Zilijstra (1968). The method is based on a constant water velocity in liters/second during the land preparation period, using Equation 4.

\[
IR=\frac{Me^k}{(e^{8T}-1)}
\]

while \(M=\text{Eo}+P\) and \(k=\frac{M \times T}{S}\)

With:
- IR = The need for irrigation water at rice field level, mm/day.
- M = Water requirement to replace/compensate for water loss through evaporation and percolation saturated paddy field, mm/day.
- \text{Eo} = Evaporation of open water taken 1.1 ET\textsubscript{o} during soil preparation.
- P = Percolation, mm/day.
- T = Land preparation period, days.
\[ S = \text{Water requirement, mm. For saturation added with a layer of water 50 mm, so } 200 + 50 = 250 \text{ mm, or if the soil is left for a period (2.5 months or more), } S \text{ value is taken 300 mm} \]

\[ e = \text{Exponential number: 2.7182} \]

Crop evaporation/consumptive use \((ET_c)\) uses water used by plants depending on the climate and plant efficiency. The crop evaporation/consumptive use can be calculated with equation 5.

\[ ET_c = K_c \times ET_o \]  

where,

\[ K_c = \text{Crop coefficient.} \]

\[ ET_o = \text{Potential Evaporation} \]

The determination of water loss through percolation \((P)\) depends on the physical properties of the soil in the study area. After inundation, the average percolation rate in clay soils varies from 1.00 to 3.00 mm/day [10]. Therefore, the percolation value used is 2.00 mm/day.

WLR (water layer replacement) replaces standing water in the rice fields with new irrigation water. Replacement of the water layer is carried out after fertilization. Replacement of the water layer is carried out as needed and is expected to be carried out in the first two months of the planting period. The WLR value in Lobalain District is 1.70 mm/day [10].

The water quality analysis was performed by taking 31 surface water samples from rice fields, reservoirs, springs, and rivers in Lobalain District, consisting of five samples from irrigation areas, 12 samples from reservoirs, seven samples from springs, and seven samples from rivers 7.

Determination of water quality is performed by field and laboratory testing of samples with parameters such as temperature, PH, EC, TDS, NH\textsubscript{3}, Cl\textsuperscript{-}, SO\textsubscript{4}\textsuperscript{2-}, K\textsuperscript{+}, NO\textsubscript{3}, Ca\textsuperscript{2+}, Mg\textsuperscript{2+}, Na\textsuperscript{+}, HCO\textsubscript{3}, and B tests, referring to laboratory tests are needed to evaluate general irrigation water quality problems [7].

Several parameters will be analyzed based on the tested parameters, including sodium (Na\%) analysis and sodium adsorption ratio (SAR) analysis. Sodium (Na\%) value is used to express the relationship between irrigation water and soil, which indicates the proportion of Na\(^+\) ions in solution and the relationship to the total cation concentration. It is useful when describing the characteristics of water, where a high value indicates soft water and a low value indicates hard water. A high Na\% value in irrigation water can inhibit plant growth and reduce the permeability of the soil. Calculation of sodium (Na\%) can be determined by equation 6.

\[ Na\% = \frac{(Na+K)\times100}{(Ca+Mg+Na-K)} \]  

*milliequivalent ion concentration per liter.

Based on sodium (Na\%) value, the water quality can be classified for agricultural irrigation purposes. The classification based on Wilcox's (1948) [8] shows in Table 1.

| Water Class   | Sodium percentage (After\%) |
|--------------|-----------------------------|
| Excellent    | < 20                        |
| Good         | 20 – 40                     |
| Permissible  | 40 – 60                     |
| Doubtful     | 60 – 80                     |
| Unsuitable   | > 80                        |

When determining water for irrigation, the sodium absorption ratio (SAR) is also taken into account. SAR is the relationship between the value of the ratio of sodium absorption and the value of water conductivity so that the quality of water can be known for agricultural irrigation purposes. The SAR calculation can be determined by equation 7.
\[ SAR = \frac{Na}{\sqrt{(Ca+Mg)}} \] (7)

*milliequivalent ion concentration per liter.

Table 2 shows the classification of the degree of suitability of the SAR value for the benefit of agricultural irrigation using the classification of Todd (1980) [9].

| SAR | Quality of Water |
|-----|-----------------|
| < 10 | Excellent       |
| 10 – 18 | Good      |
| 18 – 26 | Fair      |
| > 26 | Poor           |

3. Results and Discussion

3.1 Irrigation Water Needs

Currently, patterns and types of plants are rice-corn-fallow, with superior varieties and scheduled planting period two times a year. Based on the rainfall data used for the last seven years of 2014-2020, data were obtained on monthly rainfall and the planned planting season I (first) plan to plant season II (two), as shown in Table 3.

| Month   | Period | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---------|--------|------|------|------|------|------|------|------|
| January | I      | 49.20| 540.70| 17.40| 17.20| 255.00| 121.10| 146.70|
|         | II     | 211.00| 65.20| 102.40| 161.80| 351.90| 297.60| 265.00|
| February| I      | 139.50| 203.90| 82.70| 187.80| 19.20| 101.80| 174.60|
|         | II     | 39.30| 198.80| 108.10| 137.10| 98.80| 56.70| 80.70|
| March   | I      | 53.20| 154.00| 174.90| 126.80| 62.70| 108.20| 253.00|
|         | II     | 16.60| 149.60| 82.30| 306.70| 27.10| 105.50| 38.80|
| April   | I      | 20.40| 13.60| 2.20| 65.30| 23.20| 122.10| 43.10|
|         | II     | 28.90| 52.50| 0.00| 10.00| 14.10| 75.30| 4.50|
| May     | I      | 1.00| 0.00| 144.70| 14.30| 0.00| 14.60| 8.00|
|         | II     | 3.00| 0.00| 0.50| 0.00| 3.40| 55.80|
| June    | I      | 0.00| 4.10| 8.60| 0.00| 1.00| 1.40| 0.00|
|         | II     | 0.50| 0.00| 7.20| 4.50| 0.00| 0.00| 0.00|
| July    | I      | 0.00| 3.40| 4.70| 3.80| 1.00| 0.00| 2.40|
|         | II     | 17.30| 0.00| 0.00| 1.50| 0.00| 0.00| 0.00|
| August  | I      | 3.00| 1.00| 0.00| 0.80| 66.30| 0.00| 0.00|
|         | II     | 0.00| 0.00| 1.00| 0.00| 0.00| 0.00| 0.00|
| September| I     | 0.00| 4.80| 0.00| 0.00| 0.00| 0.00| 0.00|
|         | II     | 0.00| 0.00| 1.00| 0.00| 1.50| 0.00| 0.00|
| October | I      | 0.00| 0.00| 19.00| 29.60| 0.00| 0.00| 9.50|
|         | II     | 0.00| 0.00| 1.00| 18.00| 0.00| 0.00| 0.00|
| November| I      | 0.00| 2.70| 0.00| 49.60| 11.30| 4.30| 0.00|
|         | II     | 1.00| 0.00| 61.70| 101.20| 10.00| 2.10| 8.40|
| December| I      | 161.20| 112.40| 169.70| 176.80| 57.30| 4.20| 283.50|
|         | II     | 80.10| 96.80| 59.10| 192.20| 70.70| 52.40| 107.40|
| Amount  |       | 825.20| 1603.50| 1047.70| 1605.50| 1071.10| 1070.70| 1481.40|
| Average |       | 34.38| 66.81| 43.65| 66.90| 44.63| 44.61| 61.73|
The effective rainfall for rice ($R_{eR}$) is 70% from $R_{80}$, and the effective rainfall of corn crops ($R_{eC}$ corn) is 50% of the time in a period. The results of the calculation of effective rainfall for rice and secondary crops are shown in Table 4.

The evaporation ($E_{To}$) in each month is shown in Table 5.

**Table 4. Recapitulation of $R_{eR}$ Rice and $R_{eC}$ Corn**

| Month   | Period | $R_{80}$ | $R_{eR}$ 70% mm/day | $R_{eR}$ 50% mm/day | $R_{eC}$ 70% mm/day | $R_{eC}$ 50% mm/day |
|---------|--------|----------|----------------------|----------------------|----------------------|----------------------|
| January | I      | 351.72   | 246.21               | 16.41                | 175.86               | 11.72               |
|         | II     | 313.24   | 219.27               | 14.62                | 156.62               | 10.44               |
| February| I      | 196.49   | 137.54               | 9.17                 | 98.24                | 6.55                |
|         | II     | 156.54   | 109.58               | 7.31                 | 78.27                | 5.22                |
| March   | I      | 202.76   | 141.93               | 9.46                 | 101.38               | 6.76                |
|         | II     | 205.75   | 144.02               | 9.60                 | 102.87               | 6.86                |
| April   | I      | 82.89    | 58.02                | 3.87                 | 41.44                | 2.76                |
|         | II     | 54.59    | 38.22                | 2.55                 | 27.30                | 1.82                |
| May     | I      | 79.17    | 55.42                | 3.69                 | 39.58                | 2.64                |
|         | II     | 29.82    | 20.87                | 1.39                 | 14.91                | 0.99                |
| June    | I      | 5.37     | 3.76                 | 0.25                 | 2.69                 | 0.18                |
|         | II     | 4.68     | 3.28                 | 0.22                 | 2.34                 | 0.16                |

The irrigation water requirement is semi-monthly, with a rice-corn-fallow cultivation pattern with rice plant type of superior varieties. The calculation results of the irrigation water requirement in Table 6 show that the irrigation water requirement (NFR) used is 0.84 lt/sec/Ha.

Based on the NFR results, there is a negative value that indicates the water available is in excess so that, if properly managed, it can be reused to meet the requirements of irrigation water needs in the next planting period. Water for irrigation in 2021 with a land area of 3,762 Ha requires a water flow of around 3.159 m$^3$/sec.
Table 5. Potential Evapotranspiration Calculation Recapitulation (ETa)

| No | Description                                | Symbol | Unit | January | February | March | April | May | June | July | August | September | October | November | December |
|----|--------------------------------------------|--------|------|---------|----------|-------|-------|-----|------|------|--------|-----------|---------|----------|----------|
| 1  | Average temperature                        | T      | °C   | 27.08   | 26.82   | 26.86 | 26.80 | 26.38| 22.18| 25.06| 25.26| 25.80    | 27.10    | 27.92    | 27.87    |
| 2  | Maximum humidity                           | RH max | %    | 95.70   | 96.00   | 95.60 | 92.20 | 91.11| 83.11| 86.60| 84.20| 81.64    | 83.27    | 86.45    | 93.73    |
| 3  | Average humidity                           | RH x   | %    | 86.60   | 88.63   | 88.55 | 84.10 | 81.89| 77.72| 76.80| 73.48| 73.32    | 74.76    | 76.10    | 84.61    |
| 4  | Wind speed at elv 2m                       | U      | km/h | 6.50    | 6.41    | 3.78  | 6.50  | 10.60| 16.43| 14.31| 14.00| 10.91    | 9.77     | 8.15     | 5.77     |
| 5  | Wind speed at elv 2m                       | U2     | km/day| 155.95  | 153.79  | 90.72 | 155.95| 254.45| 394.42| 343.44| 336.10| 261.86   | 234.58   | 195.70   | 138.46   |
| 6  | Radiation Sun                              | nN     | %    | 0.53    | 0.57    | 0.58  | 0.69  | 0.78 | 0.72 | 0.77 | 0.83 | 0.85     | 0.85     | 0.80     | 0.46     |

**Evapotranspiration Calculation**

1. Saturated Vapor Pressure
   \[ ea = \text{mm bar} \]
   \[ ed = \text{mm bar} \]

2. Temperature function
   \[ f(T) = (0.25+0.50\times n/N) \times Rn \]

3. Temperature function
   \[ f(T) = 0.25 \times (1+(U2/100)) \]

4. Extraterrestrial radiation (table)
   \[ Ra = \text{mm/day} \]

5. Solar radiation
   \[ Rn = \text{mm/day} \]

6. Wind speed function
   \[ f(u) = 0.691 \times (1+(U2/100)) \]

7. Temperature function
   \[ f(T) = 0.34-0.04\times e(T) \]

8. Wind speed function
   \[ f(U) = 0.25 \times (1+(U2/100)) \]

9. Wind speed function
   \[ f(U) = 0.25 \times (1+(U2/100)) \]

10. Wind speed function
    \[ f(U) = 0.25 \times (1+(U2/100)) \]

11. Wind speed function
    \[ f(U) = 0.25 \times (1+(U2/100)) \]

12. Wind speed function
    \[ f(U) = 0.25 \times (1+(U2/100)) \]

13. Wind speed function
    \[ f(U) = 0.25 \times (1+(U2/100)) \]

14. Weight factor (temperature and elevation)
    \[ W = \text{mm/day} \]

15. Weight factor (temperature and elevation)
    \[ W = \text{mm/day} \]

16. Weight factor (temperature and elevation)
    \[ W = \text{mm/day} \]

17. Monthly evapotranspiration
    \[ ETa = c \times (Rn/(1-w)) \]

18. Monthly evapotranspiration
    \[ ETa = c \times (Rn/(1-w)) \]

19. Monthly evapotranspiration
    \[ ETa = c \times (Rn/(1-w)) \]
Table 6. Recapitulation of Irrigation Water Needs for Rice-Corn-Fallow Cropping Patterns

| Month | 15 days period - | Crop pattern | ETa | Crop Coefficient | Re | P | WLR | M = Eo + P | K = Mx (T/S) | IR | ETa + ETa.K | NFR | NFR/8.64 |
|-------|-----------------|--------------|-----|------------------|----|---|-----|------------|-------------|----|------------|------|---------|
|       |                 |              | mm/day |                 | mm/day | mm/day | mm/day | mm/day | mm/day | mm/day | mm/day | mm/day | mm/day | L/sec/ha |
| December | I  | Land preparation | 3.24 | LP | LP | LP | 10.70 | 2.00 | - | 5.56 | 0.56 | 13.04 | - | 2.34 | 0.27 |
|         | II |               | 3.24 | 1.1 | LP | LP | 6.62 | 2.00 | - | 5.56 | 0.56 | 13.04 | - | 6.42 | 0.74 |
| January  | I  | Rice 1 (Superior Variety) | 3.16 | 1.1 | 1.1 | 1.1 | 16.41 | 2.00 | 1.70 | 5.48 | 0.55 | - | 3.48 | -9.23 | -1.07 |
|         | II |               | 3.16 | 1.05 | 1.1 | 1.07 | 14.62 | 2.00 | 1.70 | 5.48 | 0.55 | - | 3.40 | -7.52 | -0.88 |
| February | I  |               | 3.01 | 1.05 | 1.05 | 1.05 | 9.17 | 2.00 | 1.70 | 5.31 | 0.53 | - | 3.16 | -2.31 | -0.27 |
|         | II |               | 3.01 | 0.95 | 1.05 | 1 | 7.31 | 2.00 | 1.70 | 5.31 | 0.53 | - | 3.01 | -0.60 | -0.08 |
| March   | I  |               | 2.76 | - | 0.95 | 0.475 | 9.46 | 2.00 | - | 5.04 | 0.50 | - | 1.31 | -6.15 | -0.71 |
|         | II |               | 2.76 | - | 0 | 9.60 | 2.00 | - | 5.04 | 0.50 | - | - | -7.60 | -0.88 |
| April   | I  | Land preparation | 2.88 | LP | LP | LP | 2.76 | - | - | 5.17 | 0.38 | 10.03 | - | 7.25 | 0.84 |
|         | II |               | 2.88 | 0.5 | 0.5 | 0.5 | 1.82 | - | - | 5.17 | 0.38 | - | 1.44 | -0.38 | -0.04 |
| May     | I  | Palawija (maize) | 2.98 | 0.59 | 0.59 | 0.59 | 2.64 | - | - | 5.27 | 0.39 | - | 1.76 | -0.88 | 0.10 |
|         | II |               | 2.98 | 0.96 | 0.96 | 0.96 | 0.99 | - | - | 5.27 | 0.39 | - | 2.86 | 1.86 | 0.22 |
| June    | I  |               | 3.38 | 0.96 | 0.96 | 0.96 | 0.18 | - | - | 5.72 | 0.45 | - | 3.24 | 3.07 | 0.35 |
|         | II |               | 3.38 | 1.05 | 1.05 | 1.05 | 0.16 | - | - | 5.72 | 0.45 | - | 3.55 | 3.39 | 0.39 |
| July    | I  |               | 3.55 | 1.02 | 1.02 | 1.02 | 0.14 | - | - | 5.90 | 0.47 | - | 3.62 | 3.48 | 0.40 |
|         | II |               | 3.55 | 0.95 | 0.95 | 0.95 | 0.31 | - | - | 5.90 | 0.47 | - | 3.37 | 3.06 | 0.35 |
| August  | I  | Fallow | 4.03 | - | - | - | - | - | - | - | - | - | - | - | - |
|         | II |               | 4.03 | - | - | - | - | - | - | - | - | - | - | - | - |
| September | I  |               | 3.98 | - | - | - | - | - | - | - | - | - | - | - | - |
|          | II |               | 3.98 | - | - | - | - | - | - | - | - | - | - | - | - |
| October  | I  |               | 4.06 | - | - | - | - | - | - | - | - | - | - | - | - |
|          | II |               | 4.06 | - | - | - | - | - | - | - | - | - | - | - | - |
| November | I  |               | 3.94 | - | - | - | - | - | - | - | - | - | - | - | - |
|          | II |               | 3.94 | - | - | - | - | - | - | - | - | - | - | - | - |
3.2 Surface Water Availability

The available surface water in Lobalain District comes from several identified surface water intakes, as shown in Table 7.

| No | Information | Quantity | Unit |
|----|-------------|----------|------|
| 1  | Pond        | 0.044    | m³/s |
| 2  | Springs     | 0.229    | m³/s |
| 3  | River       | 1.325    | m³/s |
|    | Total       | 1.598    | m³/s |

Based on data [10] and the analysis results, it can be estimated that the availability of surface water in Lobalain District is still insufficient (deficit) to meet the current need for irrigation water of 3.159 m³/second. Therefore, surface water management is needed, such as adding water storage areas in ponds/reservoirs and other water storage structures and determining cultivation patterns. In addition, there is also a need for alternative water sources that do not come from surface water.

3.3 Water Quality Test Results

The results of field measurements and chemical analysis of water samples are shown in Table 8. The most common toxicity that often occurs when using water for irrigation is chloride (Cl⁻). When the chloride concentration increases, the plant will experience excessive damage or death of plant cells, tissues, or organs. Higher chloride concentrations are associated with Pliocene sediments containing marine salts such as halite [11]. It was found that the chloride (Cl⁻) value varied from 0.03 meq/l to 18.05 meq/l. Based on FAO (1985), almost all surface water samples were classified as low (None) with Cl⁻ concentration less than 4.0 meq/l, and only one sample was classified as heavy (Severe) with Cl⁻ concentration more than 10.0 meq/l.

Nitrate (NO₃⁻) analysis has been performed to determine the nitrogen content in the water. Nitrate is a mobile and stable solute in many shallow aerobic groundwater systems. These characteristics make nitrate a contaminant concerning drinking water quality and surface water eutrophication [12]. The nitrate concentration result shows that all samples less than 5 mg/L. However, it is classified as low according to FAO (1985). In agriculture, the nitrate value in groundwater will increase if nitrogen fertilizer (urea) is too high [13].

Boron is essential to the normal growth of all plants, but the amount required is low. If it exceeds a certain level of tolerance depending on the crop, then boron may cause injury. The range between deficiency and toxicity of boron for many crops is narrow [14]. Based on Table 8, it can be seen that almost all boron values are classified as low based on FAO (1985) < 0.7 mg/l and that there is only one sample in the middle class with the value of 2.1178 mg/l at the Kolobolon area.

Ammonia (NH₃) content largely determines rice productivity in an irrigated agricultural area. If ammonia levels > 1.0 mg/l, the rice leaf growth becomes good, the fruit is empty so that the rice productivity will decrease. Table 8 shows that the value of ammonia is less than 1.0 mg/l. It is categorized into the usual range in irrigation water with a value of < 5.0 mg/l according to FAO (1985).

In agricultural irrigation planning, especially for groundwater irrigation networks, bicarbonate (HCO₃⁻) is very decisive because when the bicarbonate value is more significant, the channel's blockage gets higher, especially in closed canals. According to Singh et al., the concentration of Ca²⁺·Na⁺·Mg²⁺, and HCO₃⁻ influences permeability of soil profile [15] Based on laboratory test results, the amount of bicarbonate (HCO₃⁻) ranges from 89.4 mg/l to 498.2 mg/l, according to FAO (1985) classified as moderate (slight to moderate) with HCO₃⁻ ranging from 1.5 me/l – 8.5 me/l or 48.0 mg/l – 272.0 mg/l and the heavy (severe) is above the tolerance threshold, which is more than 272.0 mg/l or 8.5 meq/l.

High sulfate (SO₄) content in plants will cause the decomposition of organic matter, which causes unpleasant odors in agricultural products. A very high-level sulfate concentration can interfere with the absorption of other nutrients [16]. Based on the results of laboratory tests, it was found that the sulfate
value ranged from 0.12 meq/l to 6.66 meq/l, and there were only two samples with a high sulfate value. It is located in the Kolobolon area and Lifu Batu River with 4.27 meq/l and 6.66 meq/l. According to FAO (1985), these data are the usual range in irrigation water of less than 20.0 meq/l.

Table 8. Results of analysis of water quality tests in the field and the laboratory

| No | Name                | Place Sample | Field Measurement | Chemical Composition |
|----|---------------------|--------------|-------------------|---------------------|
|    |                     |              | T °C EC µS/cm TDS | NH₄⁺ Cl⁻ SO₄²⁻ NO₂⁻ | NO₃⁻ HCO₃⁻ B |
|    |                     |              | mg/l              | mg/l               | mg/l       | mg/l     |
| 1  | DI Henendam         | Pond         | 33.3 542 271 6.5  | <0.008 1.35 1.12 0.18 | 319.4 0.1431 |
| 2  | DI Kolobolon        | Pond         | 34.3 301 1505 6.9 | <0.008 18.05 4.27 0.19 | 485.4 2.1178 |
| 3  | DI Helebeek         | Rice Field   | 30.4 260 130 6.0  | <0.008 0.03 0.17 0.17 | 255.5 0.0237 |
| 4  | DI Takoic           | Pond         | 29.3 297 148 6.0  | <0.008 1.50 0.83 0.21 | 166.1 0.1217 |
| 5  | DI Nates            | Pond         | 36.8 510 287 6.6  | <0.008 1.02 1.19 0.38 | 313.0 0.02008 |
| 6  | EMB Cole            | Pond         | 36.1 100 202 8.1  | <0.008 0.98 0.31 0.01 | 121.4 0.1100 |
| 7  | EMB Takoi           | Pond         | 33.3 181 87 6.6   | <0.008 0.48 0.12 0.19 | 127.7 <0.0056 |
| 8  | EMB Kuli            | Pond         | 35.4 282 135 6.8  | <0.008 1.65 0.60 <0.01 | 134.1 0.0065 |
| 9  | EMB 03-Suelain      | Pond         | 29.4 96 46 7.7   | <0.008 0.03 0.15 0.26 | 102.2 <0.0056 |
| 10 | EMB 02-Helebeik     | Pond         | 29.6 171 84 7.0   | <0.008 0.18 0.15 0.36 | 134.1 <0.0056 |
| 11 | EMB 05-Helebeik     | Pond         | 31.2 338 162 7.0  | <0.008 2.54 0.15 0.22 | 95.8 0.1767 |
| 12 | EMB Tonggolen       | Pond         | 32.3 245 117 7.2  | <0.008 0.28 0.12 0.45 | 178.8 0.0677 |
| 13 | EMB Leukunik        | Pond         | 31.3 348 166 7.9  | <0.008 2.48 0.29 1.44 | 89.4 0.1566 |
| 14 | EMB Oeau            | Pond         | 31.6 345 166 7.1  | <0.008 3.39 0.12 0.18 | 319.4 0.7740 |
| 15 | EMB Busian          | Pond         | 32.4 379 182 6.0  | <0.008 0.62 0.37 0.07 | 286.3 0.0677 |
| 16 | EMB Todan           | Pond         | 33 228 119 7.4    | <0.008 0.80 1.00 0.13 | 306.6 0.0907 |
| 17 | EMB 02-Kolobolon    | Pond         | 33.9 169 81 6.7   | <0.008 0.68 0.12 0.22 | 166.1 0.0234 |
| 18 | MA Oelama           | Water Sources| 30.5 238 113 6.9  | <0.008 0.56 0.15 2.14 | 313.0 0.0078 |
| 19 | MA Oedale           | Water Sources| 29.2 306 141 6.0  | <0.008 2.05 0.71 0.02 | 498.2 0.0723 |
| 20 | MA Kalolimak        | Water Sources| 30.9 276 129 6.2  | <0.008 1.79 1.62 0.60 | 293.8 0.0942 |
| 21 | MA Oemasamboka      | Water Sources| 29.4 256 122 6.9  | <0.008 0.78 0.25 1.57 | 332.1 0.0248 |
| 22 | MA Oemau            | Water Sources| 28.9 267 126 6.9  | <0.008 0.73 0.21 3.20 | 332.1 0.0418 |
| 23 | MA Tanggolai        | Water Sources| 28.6 252 117 7.1  | <0.008 0.75 0.19 2.17 | 306.6 <0.0056 |
| 24 | MA Oeau             | Water Sources| 29.9 740 274 6.3  | <0.008 1.65 0.87 0.16 | 447.1 0.1310 |
| 25 | SNG 01-Suelain      | River        | 34.3 578 289 7.4  | <0.008 1.47 1.19 0.15 | 255.5 0.1438 |
| 26 | SNG 01-Helebeik     | River        | 30.5 585 292 7.4  | <0.008 2.96 1.08 0.14 | 153.3 0.1494 |
| 27 | SNG 02-Helebeik     | River        | 30.8 522 261 7.4  | <0.008 1.47 0.42 0.02 | 268.3 0.0529 |
| 28 | BNDG Letelangga     | River        | 29.7 459 230 7.2  | <0.008 0.89 0.69 1.25 | 161.9 0.0588 |
| 29 | SNG 01- Baadale     | River        | 33.2 465 232 7.1  | <0.008 0.73 0.69 0.76 | 281.0 0.0662 |
| 30 | SNG Lifu Batu       | River        | 30.4 940 470 7.0  | <0.008 2.02 6.66 0.08 | 447.1 0.2348 |
| 31 | Fakakain Waterfall  | River        | 30.8 381 190 6.7  | <0.008 0.45 0.21 1.91 | 178.0 0.0622 |

The low sodium content (Na%) in the water certainly influences crops because the low sodium content will not hinder plant growth. Based on equation 6, the percentage value of sodium (Na%) ranges from 12.66% to 86.48%. Based on this value, the sampled surface water is classified according to (Wilcox 1948) as excellent to unsuitable for use for agricultural irrigation (Table 8), so that the location used as the test point for the majority of the water quality is still quite possible to be used for agricultural irrigation water.

Based on calculations with equation 7, the SAR percentage value ranges from 0.31 to 14.38. According to those values, the sampled surface water is classified according to (Todd 1980) as excellent to good in use for agricultural irrigation, as shown in Table 9. Therefore, surface water quality in Lobalain District is very good for agricultural irrigation.
excellent class mainly dominates the sodium adsorption ratio (SAR) of the surface water.

**Table 9.** Laboratory Test Results of Na⁺, K⁺, Ca²⁺, Mg²⁺, Na% Value, and SAR

| No | Name               | Place Sample | Na⁺ meq/l | K⁺ meq/l | Ca²⁺ meq/l | Mg²⁺ meq/l | Sodium Percentage Analysis | Sodium Adsorption Ratio Analysis | Classification |
|----|--------------------|--------------|-----------|----------|------------|------------|-----------------------------|----------------------------------|-----------------|
| 1  | DI Henendam        | Rice Field   | 3.52      | 0.03     | 0.96       | 2.24       | 53.01                       | Permissible                     | Excellent       |
| 2  | DI Kolobolon       |              | 21.71     | 0.54     | 1.76       | 2.80       | 86.48                       | Unsuitable                      | Good            |
| 3  | DI Helebeik        | Rice Field   | 0.52      | 0.03     | 2.55       | 0.64       | 14.83                       | Excellent                       | Excellent       |
| 4  | DI Takoi           | Rice Field   | 1.78      | 0.05     | 1.12       | 1.04       | 47.17                       | Permissible                      | Good            |
| 5  | DI Nates           | Rice Field   | 1.78      | 0.03     | 3.16       | 1.67       | 27.47                       | Good                            | Excellent       |
| 6  | EMB Cole           | Pond         | 1.52      | 0.05     | 0.79       | 0.60       | 54.98                       | Permissible                      | Excellent       |
| 7  | EMB Takoi          |              | 0.65      | 0.08     | 1.71       | 0.24       | 28.92                       | Good                            | Excellent       |
| 8  | EMB Kuli           |              | 1.52      | 0.21     | 1.67       | 0.52       | 49.31                       | Permissible                      | Excellent       |
| 9  | EMB 03-Suelain     | Pond         | 0.26      | 0.05     | 1.11       | 0.28       | 19.50                       | Excellent                       | Excellent       |
| 10 | EMB 02-Helebeik    | Pond         | 0.52      | 0.03     | 1.77       | 0.28       | 24.43                       | Good                            | Excellent       |
| 11 | EMB 05-Helebeik    | Pond         | 1.91      | 0.03     | 1.52       | 0.28       | 52.50                       | Permissible                      | Excellent       |
| 12 | EMB Tonggolen      | Pond         | 1.52      | 0.21     | 1.85       | 0.32       | 49.58                       | Permissible                      | Excellent       |
| 13 | EMB Leukunik       | Pond         | 2.57      | 0.05     | 0.64       | 0.16       | 78.91                       | Doubtful                        | Excellent       |
| 14 | EMB Oebau          | Pond         | 4.09      | 0.23     | 4.41       | 1.09       | 46.17                       | Permissible                      | Good            |
| 15 | EMB Busian         | Pond         | 1.13      | 0.05     | 3.87       | 0.80       | 20.54                       | Good                            | Excellent       |
| 16 | EMB Todan          | Pond         | 1.52      | 0.10     | 3.69       | 1.21       | 25.73                       | Good                            | Excellent       |
| 17 | EMB 02-Kolobolon   | Pond         | 1.91      | 0.21     | 1.56       | 0.40       | 57.66                       | Permissible                      | Excellent       |
| 18 | MA Oelama          | Water Sources| 0.78      | 0.05     | 4.93       | 0.92       | 12.66                       | Excellent                       | Good            |
| 19 | MA Oedale          | Water Sources| 3.83      | 0.33     | 5.86       | 1.57       | 38.11                       | Good                            | Excellent       |
| 20 | MA Kalolimak       | Water Sources| 1.91      | 0.03     | 4.53       | 0.44       | 28.26                       | Good                            | Excellent       |
| 21 | MA Oemasamboka     | Water Sources| 1.00      | 0.03     | 4.89       | 0.96       | 15.01                       | Excellent                       | Good            |
| 22 | MA Oemau           | Water Sources| 1.00      | 0.03     | 5.38       | 0.88       | 14.18                       | Excellent                       | Good            |
| 23 | MA Tanggolai       | Water Sources| 0.91      | 0.05     | 5.01       | 0.60       | 14.89                       | Excellent                       | Excellent       |
| 24 | MA Oebau           | Water Sources| 1.78      | 0.05     | 7.50       | 1.00       | 17.92                       | Excellent                       | Excellent       |
| 25 | SNG 01-Suelain     | River        | 1.70      | 0.23     | 0.96       | 3.44       | 32.87                       | Good                            | Excellent       |
| 26 | SNG 01-Helebeik    | River        | 2.04      | 0.05     | 2.63       | 0.64       | 39.78                       | Good                            | Excellent       |
| 27 | SNG 02-Helebeik    | River        | 1.30      | 0.03     | 3.99       | 0.68       | 22.36                       | Good                            | Excellent       |
| 28 | BNDG Letelangga    | River        | 1.22      | 0.05     | 3.63       | 0.84       | 22.51                       | Good                            | Excellent       |
| 29 | SNG 01 - Baadale   | River        | 1.22      | 0.05     | 3.13       | 1.36       | 22.43                       | Good                            | Excellent       |
| 30 | SNG Lifu Batu      | River        | 3.61      | 0.21     | 4.79       | 2.20       | 36.70                       | Good                            | Excellent       |
| 31 | Fakakain Waterfall | River        | 0.83      | 0.05     | 1.48       | 1.72       | 22.10                       | Good                            | Excellent       |

4. Conclusion

The availability of surface water in the Lobalain District is 1.598 m³/second, whether from ponds, springs, and rivers. The water requirement for irrigation (NFR) in Lobalain District with a rice-corn-fallow cropping pattern in 2021 and an irrigation area of 3,762 Ha requires water of around 3.159 m³/second. The average requirement per hectare of agricultural land in each growing season is 0.84 lt/second/Ha. So there is still a shortage in the supply of surface water for irrigation. However, according to surface water quality, most surface water has a percent sodium (Na%) value ranging from excellent to permissible. Only two samples are classified as unsuitable located in Kolobolon and Leukunik. An excellent class mainly dominates the sodium adsorption ratio (SAR) of the surface water. It shows that the main water problem for irrigation in the Lobalain District is the lack of surface water resources. Therefore, it is necessary to study alternative water sources, such as groundwater sources, both in quantity and quality as an alternative source of irrigation water.
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