Determination Of Groundwater Recharge Area In Raimanuk And Surroundings, Timor Island

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Abstract, The Raimanuk area in Timor, East Nusa Tenggara, is located in the Aroki Groundwater Basin. The decreasing quality and potential groundwater availability in the Aroki Groundwater Basin is feared due to its widespread use for household needs and agriculture. The lack of the groundwater recharge area map will pose an obstacle in policymaking regarding the management and preparation of spatial conservation areas in the Raimanuk Region. This study aims to determine the zone and classification of groundwater recharge areas in the Raimanuk area based on spatial data analysis. The groundwater recharge area can be determined using slope, river flow patterns, spring emergence, and groundwater table depth. The classification of the recharge area uses a scoring approach with an overlapping analysis of the parameter assessments, which are hydraulic conductivity, precipitation, soil cover, slope, and depth of unconfined groundwater. The result of the study is the groundwater recharge area map of Raimanuk. The groundwater recharge area is located in the Mandu Hill area, which is the main recharge area. The groundwater discharge area is located in the Aroki plain area that can be the main recharge area.

Keywords: groundwater, recharge area, Raimanuk, Timor

1. Introduction
Water is a basic need of every living thing mainly used. Without water, people and other living things cannot sustain life. Water use is mainly used for basic daily needs, small-scale farming, and business needs. Water is not only used for basic daily necessities but is also used for agriculture through irrigation channels obtained from various sources. In addition to using surface water and rainwater to meet their needs, the government and community have also used large amounts of groundwater in recent years. It is due to dry surface water and low precipitation. Raimanuk area is one of the areas on Timor Island, East Nusa Tenggara. The Raimanuk area is located in one groundwater basin, namely the Aroki groundwater basin, a flat area west of the Mount Mandeu area [1]. People use the groundwater for household needs to irrigate farmland. With the increasing use of groundwater for agricultural land in the Raimanuk area, it is feared that the problem of decreasing quality and potential of groundwater availability for the Aroki groundwater basin will arise. The lack of a map of the groundwater recharge
area will pose an obstacle in policymaking regarding the management and preparation of spatial conservation areas in the Raimanuk region. Determination of the groundwater recharge area is necessary for groundwater management so that it helps to determine how much groundwater extraction can be tolerated. It is needed as consideration to make groundwater is always in the balance between availability and extraction. The problem solving will support the sustainable use of groundwater in the Raimanuk area. The position of the study area located lies in the 51S zone lines 694,936 – 713,239 m and 8,963,437 – 8,975,645 m. The north part of the study area is in West Tasifeto District. East of the research area is located in Raimanuk District and Nanuet Dubai District. The south of the research area is located in Laen Manen District. West of the research area is located in North Biboki District and Biboki Tanpah District. Morphologically, the study area is located in 2 areas: the Mandel hills area in the east and the Aroki plain area in the west.

The method widely used in zoning and classification of charging areas is spatial data analysis. The groundwater recharge area can be determined using slope, river flow patterns, spring emergence, and groundwater table depth [2]. The classification of the recharge area uses a weighting and scoring approach with an overlapping analysis of the assessment of several parameters, which are hydraulic conductivity, precipitation, soil cover, slope, and depth of unconfined groundwater [3].

2. Materials and Methods
This research was carried out in several phases, namely:

2.1. Preparation phase
It consists of a literature review to learn the basic concepts related to research and to know the field conditions. In addition, secondary data collection is in the form of regional geological data [4], soil cover type data [5], hydraulic conductivity data, precipitation data, and topographic maps obtained from DEMNAS.

2.2. Field Observation phase
It consists of collecting field data in geological observations, observing river flow patterns, observing the location of wells, and measuring the depth of the water table in dug wells.

2.3. Analysis phase
It processes data using spatial zoning methods and classifying charging areas based on multiple combined parameter maps. The determination of the charging zone is made based on [2]:
   a. Slope
      The recharge area is located above the slope, an area with tight contour lines. In contrast, the discharge area is located below the slope, an area with sparse contour lines.
   b. River flow pattern
      The recharge area can be identified in an area consisting of a series of tributaries and characterized by the area's morphology occupied by several relatively short tributaries. The recharge area is occupied by rivers of the third and fourth-order or even lower orders. The discharge area can be identified in one area consisting of the main river and several main river branches and characterized by the area's morphology occupied by the mainstream of the river or several branches of the main river with relatively long paths. The discharge area is occupied by rivers of the first and second order.
   c. The appearance of springs
      Springs are generally found in the foothills or slopes and on slopes and lower mountain slopes. The area below or downstream from where the springs appear is a groundwater discharge area. The area above or upstream from the point of appearance of the spring is a groundwater recharge area.
   d. Groundwater depth
      Areas, where the groundwater level gets deeper as the well gets deeper are recharge areas, so wells made in recharge areas generally have a deep groundwater level. Areas with shallower groundwater
levels as the well deepens are discharge areas so that wells made in discharge areas generally have shallow groundwater levels.

Recharge area classification is made using a weighting and scoring approach with an overlapping analysis of the assessment of several parameters, which are hydraulic conductivity, precipitation, soil cover, slope, and depth of unconfined groundwater [3]. Each parameter affects the water infiltration in the soil, distinguished by the weight value (Table 1). The parameter with the highest weight value is the parameter that most determines the infiltration capacity to add groundwater naturally to a groundwater basin [6], [7], [8].

| No. | Parameter                              | Weight Value |
|-----|----------------------------------------|--------------|
| 1   | Hydraulic Conductivity                 | 5            |
| 2   | Precipitation                          | 4            |
| 3   | Soil Cover                             | 3            |
| 4   | Slope                                  | 2            |
| 5   | Unconfined Groundwater Level           | 1            |

Parameter classifications are distinguished based on the value of the water infiltration capacity as stated in Table 2 to Table 6.

**Table 2. Hydraulic Conductivity Rank Value [3]**

| No. | Hydraulic Conductivity Value (m/day) | Rating Value |
|-----|--------------------------------------|--------------|
| 1   | > 10^3                               | 5            |
| 2   | 10^2 – 10^3                          | 4            |
| 3   | 10^2 – 10^4                          | 3            |
| 4   | 10^4 – 10^2                          | 2            |
| 5   | < 10^4                               | 1            |

**Table 3. Precipitation Classification Value [3]**

| No. | Precipitation (mm/year) | Rating Value |
|-----|-------------------------|--------------|
| 1   | > 4,000                 | 5            |
| 2   | 3,000 – 4,000           | 4            |
| 3   | 2,000 – 3,000           | 3            |
| 4   | 1,000 – 2,000           | 2            |
| 5   | < 1,000                 | 1            |

**Table 4. Soil Cover Rating Value [3]**

| No. | Soil Cover                  | Rating Value |
|-----|-----------------------------|--------------|
| 1   | Gravel                      | 5            |
| 2   | Gravel Sand                 | 4            |
| 3   | Sandy Clay/Sandy Silt       | 3            |
| 4   | Clay Silt                   | 2            |
| 5   | Silt Clay                   | 1            |

**Table 5. Slope Rating Value [3]**

| No. | Slope (degrees) | Rating Value |
|-----|-----------------|--------------|
| 1   | > 40            | 5            |
| 2   | 20 – 40         | 4            |
| 3   | 10 – 20         | 3            |
| 4   | 50 – 10         | 2            |
| 5   | < 5             | 1            |
Table 6. Unconfined Groundwater Depth Rating Value [3]

| No. | Unconfined Groundwater Depth (m) | Rating Value |
|-----|----------------------------------|--------------|
| 1   | > 30                             | 5 Very high  |
| 2   | 20 – 30                          | 4 High       |
| 3   | 10 – 20                          | 3 Enough     |
| 4   | 5 – 10                           | 2 Medium     |
| 5   | < 5                              | 1 Low        |

The classification of groundwater recharge areas is carried out in the following stages:

a. Giving weight value for each parameter
b. Rating each parameter
c. Adding the multiplication results between the weight values and the rating values for each parameter
d. Classifying groundwater recharge areas according to their recharge value, namely adding up the multiplication results between the weight value and the rating value for each parameter.

\[ \text{Addition value} = K_b \cdot K_p + P_b \cdot P_p + S_b \cdot S_p + L_b \cdot L_p + M_b \cdot M_p \] (1)

Information:
K = hydraulic conductivity
P = precipitation
S = soil cover
L = slope
M = unconfined groundwater depth
b = value weight
p = value rating
e. Group groundwater recharge areas into main recharge areas, additional recharge areas, and insignificant recharge areas (Table 7).

Table 7. Classification of Weighted Value Results [3]

| Application Area Classification | Weighting value |
|---------------------------------|-----------------|
| Main recharge area              | > 33            |
| Additional recharge area        | 30 – 33         |
| Insignificant recharge area     | < 30            |

3. Results and discussion
3.1. Zone Determination of Groundwater Recharge Area
The contour lines are close together in the eastern part of the study area, and the contour lines are rarely in the western part. The topography consists of plains area in the west and hilly area in the east. There are relatively short tributaries in the hilly area that flow into the plain to the center of the study area. In the plains, several major rivers converge in the south of the study area. There are four wells located in the hilly area of the eastern part of the research area in the research area. In the study area, the groundwater level of the 20 excavated wells in the western part of the study area does not exceed 10 m, so it can be said that the groundwater level is shallow. From various parameters, the groundwater recharge area with tight contours and relatively short tributaries are located in the eastern part of the study area in the Mandel Hills area of about 48.42% of the study area. The groundwater recharge area is in Lawalotolus Village and Naitimu Village, West Tasifeto District; Duabesi Village, Nanuet Duabesi District; and Duakoran Village, Faturika Village,
Mandeu Raimanus Village, Rafae Village, and Teun Village, Raimanuk District. Groundwater discharge area with sparse contours, there is the main river, downstream from the point of appearance of springs. Shallow depth of groundwater is located in the western part of the study area in the Aroki plain area of about 51.58% of the total area of the study area. The groundwater discharge area is located in Rinbesihat Village, West Tasifeto District; Meotroy Village, Laen Mane District; Boronubaen Village, East Boronubaen Village, Hauteas Village, and Taulene Village, North Biboki District; Oekopa Village, Oerinbesi Village and East T'Eba Village, Biboki Tanpah District; and Leuntolu Village, Mandeu Village and Tasain Village, Raimanuk District. The map of the recharge area and the discharge area can be seen in figure 1.

![Recharge and Discharge Zone Map](image)

**Figure 1.** Recharge and Discharge Zone Map

### 3.2. Parameters for Determination of Groundwater Recharge Area

#### 3.2.1. Hydraulic conductivity parameters

The lithology found in the study area is gravelly sand, limestone, siltstone, and basalt, as shown in Figure 2. The hydraulic conductivity parameter has a weight value of 5. Gravel-sand lithology has hydraulic conductivity values of 2.5 – 150 m/day [9]. Based on field observation, the deposits found were brown and white-brown with rounded to subcircular shapes. The size is dominated by sand and gravel. It has sedimentary material ranging from gravel to lumps found in this area and much less quantity. Areas with a hydraulic conductivity value of 2.5 – 150 m/day have a score of 20.

Limestone has a hydraulic conductivity value of 0.94 m/day [9]. Based on field observation, limestone consists of 3 units, namely crystalline limestone with fresh white color, weathered black white color, solid structure, sand grain size, good grading, closed fabric, composed by bioclastic material, and carbonate material. Coral limestone has a white-brown color, with a layered structure, grain size from sand to gravel, poor grading, open fabric, composed of bioclastic material, and carbonate material. Wackestone limestone has white-brown fresh color, weathered black-brown color, solid structure, fine sand to silt size, good grading, closed fabric, and composed of carbonate material. Areas with a hydraulic conductivity value of 0.94 m/day have a score of 15.
Siltstone has a hydraulic conductivity value of 0.08 m/day [9]. Based on field observation, the carbonated siltstone has a brown-white, red, black, green white color, layered or laminated structure, mud grain size, good grading, a closed fabric composed of siliciclastic material, carbonate material, and iron oxide minerals. Areas with a hydraulic conductivity value of 0.08 m/day have a score of 15. Basalt has a hydraulic conductivity value of 0.01 m/day [9]. Based on field observation, basaltic lava has fresh gray-brown color and weathered brown color, with a solid structure, porphyrophanitic texture, phenocryst size 0.5 – 2 mm, basalt mass < 0.5 mm, composition in the form of plagioclase, and mafic minerals. Areas with a hydraulic conductivity value of 0.01 m/day have a score of 15. These areas can be classified into two regions [3]. Calculations and scores can be seen in Table 8.

![Figure 2. Geologic Map of Raimanuk and Surrounding Areas](image)

### Table 8. Calculation of Hydraulic Conductivity Parameter Score

| Hydraulic Conductivity Value (m/day) | Rating Value | Weight Value | Score |
|-------------------------------------|--------------|--------------|-------|
| $10^1$ – $10^3$                    | 4            | 5            | 20    |
| $10^2$ – $10^1$                    | 3            | 5            | 15    |

#### 3.2.2. Precipitation parameters

The precipitation parameter has a weight value of 4. Based on observations and recordings of The Sukabitetek weather station, the annual precipitation data for ten years from 2011 to 2020 is obtained. The average yearly precipitation is 1,333.9 mm/year. The study area consists of 1 rain class [3] (Figure 3). It is because the rainfall in the study area is between 1,000 and 2,000 mm/year. Areas with precipitation of 1,000 – 2,000 mm/year are in 4th rank, so the rating value multiplied by the weight value has a score of 8. The calculations and scores can be seen in Table 9.

### Table 9. Calculation of The Precipitation Parameter Score

| Precipitation (mm/year) | Rating Value | Weight Value | Score |
|-------------------------|--------------|--------------|-------|
| 1,000 - 2,000           | 2            | 4            | 8     |
Figure 3. Precipitation Parameter Map

3.2.3. Soil cover parameters

The soil types in the study area are typic ustorthents, lithic haplustolls, typic epiaquepts, typic haplустalfs, typic haplusstepts. Some areas in the form of rock outcrops have no soil, as shown in Figure 4 [5]. The soil cover parameter has a weight value of 3. Typic ustorthents soil type contains gravel sand [10]. The gravel sand cover area is in 4th rank, so it has a score of 12. Lithic haplustolls, typic epiaquepts, typic haplустalfs, and typic haplusstepts soil type contains sandy silt [10]. Areas with sandy silt cover are in rank 3rd, so they have a score of 9. The rock outcrop area has no soil allowing water to be absorbed directly without obstruction. As the rating value for rock outcrops does not exist, it is assumed that outcrops fall into the gravel level and score 15. These areas can be divided into three regions [3]. Calculations and scores can be seen in Table 10.

Figure 4. Soil Type Map
Table 10. Calculation of Soil Cover Parameter Score

| Soil Cover      | Rating Value | Weight Value | Score |
|-----------------|--------------|--------------|-------|
| Gravel          | 5            | 3            | 15    |
| Gravel Sand     | 4            | 3            | 12    |
| Sandy Clay/Sandy Silt | 3    | 3            | 9     |

3.2.4. Slope parameter

The slope parameter has a weight value of 2. The study area has different slope values, as shown in Figure 5. Variations in slope in the study area can be classified into five areas [3]. Areas with a slope > 40° are in rank 5th, so they have a score of 10. Areas with a slope of 20° – 40° are in rank 4th, so they have 8. Regions with a slope of 10° – 20° are in rank 3rd, so they have 6. Areas with a slope of 5° – 10° are in rank 2nd, so they have a score of 4. Areas with a slope < 5° are ranked 1st, so they have a score of 2. The calculations and scores are shown in Table 11.

![Slope Map of Research Area](image)

Figure 5. Slope map

Table 11. Calculation of Slope Parameter Score

| Slope (degrees) | Rating Value | Weight Value | Score |
|-----------------|--------------|--------------|-------|
| > 40            | 5            | 2            | 10    |
| 20 – 40         | 4            | 2            | 8     |
| 10 – 20         | 3            | 2            | 6     |
| 5 – 10          | 2            | 2            | 4     |
| < 5             | 1            | 2            | 2     |

3.2.5. Unconfined groundwater depth parameters

The parameter unconfined groundwater depth has a weight value of 1. From the groundwater level depth measurement at 20 excavated well points, the depth of the groundwater table varies from 0.01 to 9.59 m, as can be seen in Table 12. The depth of the unconfined groundwater table in the study area can be...
divided into two classes [3]. Areas with an unconfined groundwater table of 5 – 10 m have a score of 2. Areas with an unconfined groundwater level depth of < 5 m have a score of 1. The calculations and scores are shown in Table 13.

Table 12. Unconfined Groundwater Depth Value

| No. | Coordinates (UTM) | Elevation (masl) | Groundwater Table (masl) | Depth (m) |
|-----|-------------------|-----------------|--------------------------|-----------|
| 1   | 705.608.531       | 8,970,125.411   | 367.955                  | 358.365   | 9.590 |
| 2   | 705.572.214       | 8,970,183.985   | 369.098                  | 360.198   | 8.900 |
| 3   | 705.062.519       | 8,974,468.136   | 387.578                  | 385.968   | 1.610 |
| 4   | 705.060.966       | 8,974,419.712   | 385.816                  | 380.736   | 5.080 |
| 5   | 703.357.135       | 8,970,038.594   | 349.403                  | 348.643   | 0.760 |
| 6   | 703.345.236       | 8,970,072.044   | 349.185                  | 348.465   | 0.720 |
| 7   | 703.256.057       | 8,970,077.128   | 347.689                  | 347.589   | 0.100 |
| 8   | 702.937.324       | 8,970,852.826   | 351.745                  | 351.145   | 0.600 |
| 9   | 701.927.353       | 8,972,167.809   | 359.511                  | 357.811   | 1.700 |
| 10  | 701.424.110       | 8,972,746.263   | 365.474                  | 359.734   | 5.740 |
| 11  | 701.141.612       | 8,972,417.357   | 368.287                  | 362.067   | 6.220 |
| 12  | 700.620.556       | 8,966,617.506   | 337.001                  | 334.181   | 2.820 |
| 13  | 700.270.217       | 8,967,897.765   | 338.262                  | 336.312   | 1.950 |
| 14  | 700.358.614       | 8,966,445.694   | 338.830                  | 335.560   | 3.270 |
| 15  | 699.664.767       | 8,968,571.700   | 343.172                  | 342.712   | 0.460 |
| 16  | 699.266.422       | 8,968,904.795   | 350.281                  | 349.121   | 1.160 |
| 17  | 697.192.868       | 8,966,169.870   | 361.564                  | 355.734   | 5.830 |
| 18  | 696.738.488       | 8,967,037.109   | 370.855                  | 367.275   | 5.580 |
| 19  | 696.653.719       | 8,965,451.384   | 368.637                  | 365.507   | 3.130 |
| 20  | 696.616.108       | 8,965,370.848   | 370.000                  | 367.530   | 2.470 |

Table 13. Calculation of Unconfined Groundwater Depth Parameter Score

| Unconfined Groundwater Depth (m) | Rating Value | Weight Value | Score |
|----------------------------------|--------------|--------------|-------|
| 5 - 10                           | 2            | 1            | 2     |
| < 5                              | 1            | 1            | 1     |

Figure 6. Total Weighted Map
3.2.6. Weighting results
The weighting result is the sum of each parameter value according to Equation 1. Areas with a value above 33 can act as main recharge areas, and areas with values from 30 to 33 are additional recharge areas. In contrast, areas with values below 30 are an area with insignificant recharge area [3]. The maximum value obtained from the weighting results is 50, while the minimum value is 36 (Figure 6), so the entire research area is the primary recharge area. Although all of these areas are considered recharge areas, Aroki plain still acts as groundwater discharge areas. This area, characterized by sparse contours, is the location of the main river flowing downstream from the point of appearance of springs. Moreover, the Aroki plain also has a shallow depth of groundwater.

4. Conclusion
The groundwater recharge area is located in the eastern part of the study area, classified as the main recharge area. The groundwater discharge area is in the western part of the study area, acting as the main recharge area. The groundwater recharge area comprises 48.42% of the Raimanuk area, covering Lawalutolus Village and Naitimu Village, West Tasifeto District; Duabesi Village, Nanuet Duabesi District; and Duakoran Village, Faturika Village, Mandeu Raimanus Village, Rafae Village, and Teun Village, Raimanuk District. About 51.58% of the Raimanuk area is the groundwater discharge area which is Rinbesihat Village, West Tasifeto District; Meotroy Village, Laen Manen District; Boronubaen Village, East Boronubaen Village, Hauteas Village, and Taulene Village, North Biboki District; Oekopa Village, Oerinbesi Village, and East T'Eba Village, Biboki Tanpah District; and Leuntolu Village, Mandeu Village, and Tasain Village, Raimanuk District. The groundwater recharge area classified as the main recharge area is the Mandeu hills area. In contrast, the groundwater discharge area is the Aroki plain.

By determining this groundwater recharge area, the government can use it as a reference for making regional spatial plans. The recommendation for groundwater recharge area is to make it a protected forest area and monitor development progress. In groundwater discharge areas, monitoring the use and utilization of groundwater must be carried out so that the problem of decreasing the quality and potential availability of groundwater in the Aroki groundwater basin will not occur.

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