Analysis of micro-hydro potential based on landuse planning in the Kelara watershed

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Abstract. Energy needs to become an inseparable part of the community's living needs, along with the rapid increase in development. The supply of electricity is carried out by PT PLN (Persero), as an official institution appointed by the government to manage electricity problems in Indonesia, so far it has not been able to meet the community's need for electricity as a whole. So, it is necessary to develop the potential for renewable energy such as hydropower. Potential water resources that can be used as sources of electrical energy such as the Hydroelectric Power Plant and Micro-Hydro Power Plant. Based on these problems, this research was conducted to analyze the potential of micro-hydro using the Geographic Information System method with the Soil and Water Assessment Tool (SWAT) model and the application of spatial pattern plans to increase potential areas in micro-hydro development in Kelara Watershed, South Sulawesi. This research uses the Soil Water Assessment Tool (SWAT) model approach and the calculation of hydraulic power. Classification of land cover in 2015 in Kelara watershed with vegetation is 6,469.45 ha (16.81%) of the total area of the watershed. The results showed that with 2015 land cover conditions, there were 22 sub-watersheds with the potential for micro-hydro development from 83 sub-watersheds in Kelara Watershed. Assuming a minimum of 10 kW of power is generated at any time, 12 sub-watersheds are obtained, which can be used for micro-hydropower plants. The implementation of the spatial plan in 2031 can reduce the number of potential sub-watersheds based on minimum discharge. The condition of land cover in 2015 amounted to 22 sub-watersheds, while in the spatial plan, there are 21 potential sub-watersheds.

1. Introduction
Along with the rapid increase in development in the fields of technology, industry, and information, electrical energy needs become an inseparable part of the daily needs of the community. The supply of electrical energy carried out by PT PLN (Persero) until now is still limited [1].

Nowadays, natural resources are threatened by their existence and function as a buffer for living systems [2]. The increase in population also affected the increasing use of fossil fuels. Electricity is a basic need of the community that can support regional development and increases community productivity. The high use of fossil-based energy will cause damage to the environment, such as global warming [3].
Potential water resources that can be used as sources of electrical energy such as the Hydroelectric Power Plant and Micro-Hydro Power Plant. Using electricity from hydropower can reduce the consumption of fossil energy such as coal, oil, and gas and efforts to preserve the environment.

Renewable energy potential needs to be developed, such as hydropower in remote areas (off-grid). The Micro Hydro Power Plant is an alternative that is suitable to be built in areas that have high topography and have many tributaries and have a large enough hydropower potential. To assess the potential of micro-hydro in a watershed, daily water discharge data and waterfall height are needed. River discharge data currently available from the government are only for main rivers, while the data needed is for each river flow. So, to conduct a study in a large area, and there are many river flows, manual discharge measurement is not effective and requires a long time.

Models for analyzing discharges have been developed, three of which are the most popular are Gridded Surface/Subsurface Hydrologic Analysis, The Hydrologic Modeling System (HEC-HMS) and Soil and Water Assessment Tool (SWAT). These models have advantages and disadvantages, but what is used is the SWAT model because it has a medium complexity and can be used for continuous analysis. Besides, it can be used for the analysis of various land cover [4]. The use of the SWAT model for spatial analysis is ArcSWAT. ArcSWAT is an analysis tool that is linked to geographic information systems. To use the SWAT model, land cover/land use data, soil type data, slope data, and daily climate data are needed [5]

Land use planning is needed because it is one of the efforts that can be done to restore the function of the water system so that water is available at all times. Land-use planning that has been made by local government in the Regional Spatial Planning is an ideal plan for the welfare of the community at the end of the planning year.

Based on the description above, micro-hydopower is suitable to be developed in Kelara Watershed because it is a mountainous area with many water sources. Then it is necessary to conduct research on the analysis of micro-hydro potential using the Geographic Information System method with the Soil and Water Assessment Tool (SWAT) model and the application of the spatial plan to increase the potential area for micro hydro development.

2. Research methods

2.1. Research area
The location boundary of this study was obtained from the DEM Aster analysis. Administratively the Kelara Watershed covers Gowa and Jeneponto Regencies, as shown in Figure 1.
2.2. Research procedure

The research mechanism in analysis in Kelara watershed by using a simulation model that is able to describe the phenomena and hydrological characteristics of the watershed. The stages in the simulation model include three stages, and those are (1) variable input, (2) running model process, and (3) defining the output of the simulation model analysis (discharge). Research stages as in Figure 2.

Figure 1. Research Location
2.3 Data accuracy test
An accuracy test is performed for the results of image interpretation. Accuracy is a comparison between the results of image classification with an existing condition in the field. According to Lille and Kiefer (1997) [6], the level of accuracy of image interpretation that is acceptable is 85%. The accuracy testing process is called overall accuracy with the following equation.

$$ \text{Overall Accuracy Calculation} \ OA = \frac{X}{N} \times 100\% $$

where:
X : The corresponding number of points
N : The sum of all points

2.3.1. SWAT model simulation. The simulation process will run after adding climate data to the model. Climate data is based on daily data for the period 2004-2013. After the simulation is completed by using the Run SWAT, a daily discharge result is obtained for 10 years.

2.3.2. Calibration. Calibration aims to ensure that the output of a model used approaches the observation output. According to Nash and Sutcliffe (1970) [6] in Nursaputra (2015) [7], calculating the accuracy of the method used predicts the outcome with an objective function. The objective function that can be used is the coefficient of determination (R2). R2 values close to 1 indicate a close relationship between the
results of the model and the results of observations. The $R^2$ value for the discharge data can be determined through the following equation.

$$R^2 = \frac{\sum_i^n (Q_{\text{Obs},i} - \bar{Q}_{\text{Obs},i})(Q_{\text{Mod},i} - \bar{Q}_{\text{Mod},i})^2}{\sum((Q_{\text{Obs},i} - \bar{Q}_{\text{Obs},i}))^2 \sum((Q_{\text{Mod},i} - \bar{Q}_{\text{Mod},i}))^2}$$

where:

$Q_{\text{Obs},i}$ : observation discharge (m$^3$/s)

$Q_{\text{Mod},i}$ : model discharge (m$^3$/s)

$\bar{Q}_{\text{Obs},i}$ : average observation discharge (m$^3$/s)

$\bar{Q}_{\text{Mod},i}$ : average model discharge (m$^3$/s)

2.3.4. Calculation of micro hydro potential. Potential calculations can be done with the water hydraulic power equation, i.e. [4]:

$$\text{Pairs} = pgQhe$$

where:

$\text{Pairs}$ : Hydraulic power generated (Watts)

$p$ : Mass type of water (1000 kg/m$^3$)

$g$ : Gravity acceleration constant (9.81 m/sec$^2$)

$Q$ : Discharge (m$^3$/sec)

$h$ : High water fall / Head (m)

$e$ : Turbine efficiency (0.7 or 70%)

2.3.5. Calculation of the Number of House. To calculate the number of houses that can supply electricity, the following calculation is used [8];

$$\text{Number of Houses} = \frac{\text{Power Generated}}{\text{Minimum Electricity needs}}$$

2.3.6. Determination of potential watersheds. With a minimum height of 3 meters and a minimum flow of 0.3 m$^3$/s there is potential for micro-hydro development. As well as assuming the power generated at any time is 10 kW equivalent to electricity supply to 100 houses.

3. Results and Discussion

3.1. Land Cover in 2015

The results of the analysis of land cover obtained from the interpretation of Landsat 8 imagery and detailed through field observation in Kelara Watershed can be known as 9 classes of land cover. In order to be readable by the SWAT model, the results of the interpretation of the imagery and field check of the land cover are transformed according to the naming of the land cover of the SWAT model. As shown in Table 1.

| No | Land Cover Category       | Land Cover in SWAT | Area (ha)   |
|----|--------------------------|--------------------|-------------|
| 1  | Primary Dry Land Forest  | Forest-Mixed       | 305.33      |
| 2  | Secondary Dry Land Forest| Forest-Mixed       | 5.487.49    |
| 3  | Plantation Forest        | Rice               | 676.63      |
| 4  | Settlement               | Residential        | 1.227.61    |
| 5  | Plantation               | Orchard            | 11.240.09   |
| 6  | Dryland farming          | Agriculture Land-Generic | 10.896.05  |
Forest vegetation is only 16.81% of the Kelara watershed area. The percentage was obtained from primary dryland forest with an area of 305.33 ha (0.79%), secondary dryland forest with an area of 5,487.49 ha (14.26%), and plantation forest with an area of 676.63 ha (1.76%). The forest area is still far below the minimum standard stipulated in Law No. 41 of 1999 [9] that the minimum area of forest in a Watershed is 30%.

3.2. Spatial Pattern Plan for 2012 - 2031
Regional spatial plans are part of the development of an area that is expected to be able to provide the best plan to increase the productivity of an area. The implementation of the spatial plan with the land cover approach is then translated into the SWAT model land cover classification, as shown in Table 2. The use of the spatial plan in the SWAT model is expected to be better than the 2015 land cover, in this case, water discharge data.

| No | Land Cover Category | Land Cover in SWAT | Area (ha) |
|----|---------------------|--------------------|-----------|
| 7  | Rice fields         | Rice               | 8,215,01  |
| 8  | Pond                | Water              | 207,65    |
| 9  | Water Body          | Water              | 225,34    |
|    | Total               |                    | 38,481,21 |

Table 2. Classification of Land Cover in Regency Spatial Pattern

| No | Spatial Pattern         | Land Cover        | Land Cover SWAT classification | Area     |
|----|-------------------------|-------------------|-------------------------------|----------|
| 1  | Agroforestry            | Plantation        | Orchard                       | 1,772,96 | 4.61    |
| 2  | Paddy field Area        | Paddy field       | Rice                          | 10,833,14| 28.15   |
| 3  | Protection Forest       | High-Density Dryland Forest Area | Forest-Mixed | 4,182,14 | 10.87   |
| 4  | Limited Production Forest | Plantation Forest | Forest-Evergreen              | 3,133,26 | 8.14    |
| 5  | Production Forest       | Plantation Forest | Forest-Evergreen Agriculture Land-Generic | 828,08 | 2.15    |
| 6  | Horticulture Area       | Dryland Agriculture |                       | 6,904,45 | 17.94   |
| 7  | Plantation Area         | Plantation        | Orchard                       | 397,78  | 1.03    |
| 8  | Agriculture Dryland Area | Dryland Agriculture | Agriculture Land-Generic | 6,973,10 | 18.12   |
| 9  | Protection Area         | High-Density Forest Area | Forest-Mixed | 52,29  | 0.14    |
| 10 | Waterbody               | Waterbody         | Water                         | 213,17  | 0.55    |
| 11 | Settlement Area         | Settlement        | Residential                   | 1,494,78 | 3.88    |
| 12 | Animal Husbandry Area   | Savanna           | Pasture                       | 1,692,28 | 4.40    |
| 13 | Pond Area               | Pond              | Water                         | 3,78    | 0.01    |

Grand Total 38,481,21 100.00
In a spatial pattern, spatial allotment is either for protection functions and cultivation functions. The results of the translation of spatial patterns into the land cover classification of Kelara watershed are only 21.30% of Kelara watershed. The percentage consists of the high density of dryland forest (in the pattern of protected forest and Regency protected area) with an area of 4,234.43 ha (11%), and plantation forests (in the pattern of limited production forest and production forests with an area of 3,961.34 ha (10.29%). The forest area is still far below the minimum standard stipulated in Law Number 41 of 1999 that the minimum area of forest in a Watershed is 30%.

The application of the spatial pattern is expected to increase or maintain the stability of river water discharge. If the spatial pattern plan is applied in the present condition, there will be a comparison of land cover in the Kelara Watershed, as shown in Table 3.

| No | Land Cover Classification from Spatial Pattern | Land Cover in 2015 | Area (ha) | (%) |
|----|-----------------------------------------------|-------------------|-----------|-----|
| 1  | High-Density Dryland Forest Area              |                   |           |     |
|    | Primary Dryland Forest                        | 305,33            | 0,79      |     |
|    | Secondary Dryland Forest                      | 2,406,00          | 6,25      |     |
|    | Plantation Forest                             | 420,43            | 1,09      |     |
|    | Settlement                                    | 0,003             | 0,00      |     |
|    | Plantation                                    | 314,83            | 0,82      |     |
|    | Dryland Agriculture                           | 609,5             | 1,58      |     |
|    | Paddy Field                                   | 161,74            | 0,42      |     |
|    | Waterbody                                     | 16,59             | 0,04      |     |
|    | Sub-Total                                     | 4,234,43          | 11,00     |     |
| 2  | Plantation Forest                             | 2,424,91          | 6,30      |     |
|    | Secondary Dryland Forest                      | 194,19            | 0,50      |     |
|    | Plantation                                    | 22,31             | 0,06      |     |
|    | Plantation                                    | 348,68            | 0,91      |     |
|    | Dryland Agriculture                           | 862,76            | 2,24      |     |
|    | Paddy Field                                   | 104,68            | 0,27      |     |
|    | Waterbody                                     | 3,81              | 0,01      |     |
|    | Sub-Total                                     | 3,961,34          | 10,29     |     |
| 3  | Savanna                                       | 18,58             | 0,05      |     |
|    | Settlement                                    | 1,565,72          | 4,07      |     |
|    | Dryland Agriculture                           | 68,89             | 0,18      |     |
|    | Waterbody                                     | 39,1              | 0,10      |     |
|    | Sub-Total                                     | 1,692,28          | 4,40      |     |
| 4  | Settlement                                    | 0,15              | 0,00      |     |
|    | Settlement                                    | 986,93            | 2,56      |     |
|    | Plantation                                    | 3,16              | 0,01      |     |
|    | Dryland Agriculture                           | 287,02            | 0,75      |     |
|    | Paddy Field                                   | 206,37            | 0,54      |     |
| No | Land Cover Classification from Spatial Pattern | Land Cover in 2015 | Area (ha) | (%) |
|----|-----------------------------------------------|-------------------|----------|-----|
|    |                                               | Waterbody         | 11,16    | 0,03 |
|    | Sub-Total                                     |                   | **1,494,78** | **3,88** |
| 5  | Plantation                                    | Secondary Dryland Forest | 418,59    | 1,09 |
|    |                                              | Plantation Forest | 21,23    | 0,06 |
|    |                                              | Settlement        | 3,44     | 0,01 |
|    |                                              | Plantation        | 273,67   | 0,71 |
|    |                                              | Dryland Agriculture | 1,368,82 | 3,56 |
|    |                                              | Paddy Field       | 84,33    | 0,22 |
|    |                                              | Waterbody         | 0,65     | 0,00 |
|    | Sub-Total                                     |                   | **2,170,73** | **5,64** |
| 6  | Dryland Agriculture                           | Secondary Dryland Forest | 92,61    | 0,24 |
|    |                                              | Plantation Forest | 40,64    | 0,11 |
|    |                                              | Settlement        | 146,92   | 0,38 |
|    |                                              | Plantation        | 6,861,38 | 17,83 |
|    |                                              | Dryland Agriculture | 4,966,37 | 12,91 |
|    |                                              | Paddy Field       | 1,463,79 | 3,80 |
|    |                                              | Pond              | 207,6    | 0,54 |
|    |                                              | Waterbody         | 98,24    | 0,26 |
|    | Sub-Total                                     |                   | **13,877,55** | **36,06** |
| 7  | Paddy field                                   | Secondary Dryland Forest | 145,37   | 0,38 |
|    |                                              | Settlement        | 48,91    | 0,13 |
|    |                                              | Plantation        | 3,392,31 | 8,82 |
|    |                                              | Dryland Agriculture | 1,164,52 | 3,03 |
|    |                                              | Paddy Field       | 6,071,49 | 15,78 |
|    |                                              | Waterbody         | 10,54    | 0,03 |
|    | Sub-Total                                     |                   | **10,833,14** | **28,15** |
| 8  | Pond Area                                     | Settlement        | 0,01     | 0,00 |
|    |                                              | Dryland Agriculture | 3,72     | 0,01 |
|    |                                              | Pond              | 0,05     | 0,00 |
|    | Sub-Total                                     |                   | **3,78** | **0,01** |
| 9  | Waterbody                                     | Settlement        | 0,5      | 0,00 |
|    |                                              | Plantation        | 46,06    | 0,12 |
|    |                                              | Dryland Agriculture | 67,62    | 0,18 |
|    |                                              | Paddy Field       | 53,74    | 0,14 |
|    |                                              | Waterbody         | 45,25    | 0,12 |
|    | Sub-Total                                     |                   | **213,17** | **0,55** |
|    | Total                                         |                   | **38,481,21** | **100,00** |
According to the comparison, it is found that many land cover conditions are not in accordance with the spatial pattern plan. The direction for high-density dryland forests is known that there is a non-vegetation area of 26.04%, which according to forest spatial planning, while in the direction for plantations forest, there are still 33.88% of the non-vegetation area.

3.3. Soil Hydrology

Soil hydrological group is a grouping of land based on the potential surface runoff, which is determined based on the infiltration rate, soil physical properties (texture, structure, porosity, depth, etc.) [9]. Soil hydrology is determined based on a soil detail map (RePPProt), and the USDA Soil Web is then classified based on the physical properties of the soil. The SCS land cover complex classification consists of three factors: soil depth, texture, and hydrological state. As in Table 4.

| No | Soil Type | SWAT Code | Soil Texture | Hydrology Group |
|----|-----------|-----------|--------------|----------------|
| 1. | Dystropepts; Haplorthox; Tropudults | SOIL01 | Silty Clay - Silty Clay Loam- Silty Loam | A |
| 2. | Dystropepts; Humitropepts; Tropohumults | SOIL02 | Silty Clay - Silty Clay - Silty Loam | A |
| 3. | Dystropepts; Humitropepts; Tropudalfs | SOIL03 | Silty Clay - Silty Clay - Silty Clay Loam | A |
| 4. | Dystropepts; Tropudalfs; Tropudults | SOIL04 | Silty Clay - Silty Clay Loam- Silty Loam | A |
| 5. | Dystropepts; Tropudults | SOIL05 | Silty Clay - Silty Loam | A |
| 6. | Dystropepts; Tropudults; Troperthents | SOIL06 | Silty Clay - Silty Loam – Sand | A |
| 7. | Haplustults; Ustropepts; Eutrochox | SOIL07 | Silty Loam - Silty Clay Loam- Silty Loam | A |
| 8. | Humitropepts; Dystrandepts; Hydrandepts | SOIL08 | Silty Clay - Silty Clay - Silty Clay Loam | B |
| 9. | Tropudalfs; Ustropepts; Tropudults | SOIL09 | Silty Clay Loam - Silty Clay Loam- Silty Loam | D |
| 10. | Ustropepts; Haplustalfs | SOIL10 | Silty Clay Loam - Silty Loam | A |
| 11. | Ustropepts; Haplustults; Haplustalfs | SOIL11 | Silty Clay Loam - Silty Loam - Silty Loam | A |
| 12. | Ustropepts; Paleustults; Haplustults | SOIL12 | Silty Clay Loam - Silty Loam - Silty Loam | A |
| 13. | Ustropepts; Tropaquepnts | SOIL13 | Silty Clay Loam - Loamy Sand | A |

Soil hydrology group A has the smallest runaway water potential and a high infiltration rate. Soil hydrological group B has a small runaway water potential and a moderate infiltration rate. Soil hydrological group C has moderate runoff water potential, and low infiltration rate, whereas soil hydrological group D has high runoff water potential and low infiltration rate [10].
3.4. Potential areas
Determination of potential areas by using the SWAT model for delineation of Kelara watershed so that hydrological data based on the complete DEM are obtained, including river network maps, boundary maps, as well as sub-watershed and outlet maps. The classification of sub-watershed is one of SWAT model procedure which classified the location based on the river outlet, as shown in Figure 3.

![Figure 3. Map of Delineation of Sub-Watershed in Kelara Watershed](image)

The number of sub-watersheds formed is 83 sub-watersheds, but not all of them have the potential for the development of micro hydropower.

3.5. Height of waterfall (Head)
Head is the vertical distance of water falling in meters, besides Head is also interpreted as water pressure. In this research, the height of the waterfall was obtained by the different height contours, which had an interval of 1 meter with the other distance. The height of waterfall data was obtained by the measurement by using contour. Most of this sub-watershed location has 3 meters high of a waterfall, but there are two sub-watersheds that do not have waterfall height.

The higher the slope of the place, the more likely it is to obtain head height. A higher head will produce higher pressure, output on a larger turbine. This is in accordance with research conducted by Sukamta and Kusmantoro (2013) [11], which states that the more oblique a location is, the more likely it is to find enough heads for Micro Hydro Power Plant.
3.6. Water discharge Model with Land Cover

According to simulation results of the Kelara Watershed hydrological condition using a SWAT model based on the 2015 land cover, we found that the water discharge data which could determine the development of micro-hydro. The increasingly problematic hydrological conditions of watersheds are indicated by the presence of several sub-watersheds that do not meet the minimum water discharge for the use of micro-hydro, which is equal to 0.3 m³/s. Sub-watershed location that meets the minimum water discharge for micro-hydro energy development, as shown in Figure 4.

![Figure 4. Potential Micro Hydro Power Plant Based on 2015 Land Cover](image)

Figure 4 shown that the water discharge in 22 sub-watersheds has a water discharge value above the minimum water discharge for micro-hydro potential. However, there are several sub-watersheds whose water discharge values approach 0.3 m³/s, the decrease in water discharge occurred between July and October. Water discharge can affect the power generated by micro-hydro plants, and the greater the water discharge, the greater the power generated. The minimum water discharge for a period of 1 year in 22 Sub-watersheds can be seen in Table 5

The location that has the lowest minimum water discharge is in sub-watershed 32 (0.30 m³/s), and the location that has the highest minimum debit is in sub-watershed 81 (2.25 m³/s). High and low water discharge can be influenced by land and climate condition in each sub-watershed.

3.7 Water discharge Model with a Spatial Pattern Plan

The implementation of the spatial pattern plan is expected to contribute to the availability of water discharge in the watershed, which can be utilized as micro-hydro energy. From the simulation results of the Kelara Watershed hydrological condition by using the SWAT model based on a spatial pattern plan that is translated into land cover classification, water discharge data are obtained, which determine the development of micro-hydro energy. In the application of the spatial pattern, there are some sub-
watershed that do not meet the minimum discharge for the use of micro-hydro, which is equal to 0.3 m$^3$/s. Sub-watershed areas that meet the minimum discharge to develop micro-hydro energy, as shown in Figure 5.

![Daily Discharge Graph](image)

Figure 5. Micro Hydro Power Plant Potential Based on Spatial Patterns

It can be seen that the total water discharge in 21 Sub-watersheds has a discharge value above the minimum discharge for micro-hydro potential. However, there are some sub-watersheds whose discharge values approach the value of 0.3 m$^3$/s as shown in Figure 5, the decrease in discharge occurred between July and October. Discharge can affect the power generated by micro-hydro power plants, and the bigger the discharge, the bigger the power generated, but it is important to consider the high waterfall factor. To see further information of minimum discharge for a period of 1 year in 21 Sub-watersheds shown in Table 7.

The area that has the lowest minimum debit is in Sub DAS 20 of 0.37 m$^3$/s, and the area that has the Sub-watershed 20 has the lowest minimum water discharge (0.37 m$^3$/s), and sub-watershed 81 has the highest minimum water discharge (2.25 m$^3$/s). This condition can be influenced by land and climate conditions in each sub-watershed.
Table 5. Comparison of Minimum Water discharge in Sub-watershed with the input of Land Cover and Regency Spatial Plan in 2015

| No | Sub-watershed      | Minimum Water discharge based on Land Cover (m$^3$/s) | Minimum Water discharge based on Spatial Pattern (m$^3$/s) |
|----|--------------------|------------------------------------------------------|----------------------------------------------------------|
| 1  | Sub-watershed 20   | 0.36                                                 | 0.37                                                     |
| 2  | Sub-watershed 23   | 0.4                                                  | 0.4                                                      |
| 3  | Sub-watershed 32   | 0.3                                                  |                                                          |
| 4  | Sub-watershed 33   | 0.43                                                 | 0.42                                                     |
| 5  | Sub-watershed 38   | 0.5                                                  | 0.48                                                     |
| 6  | Sub-watershed 40   | 0.48                                                 | 0.48                                                     |
| 7  | Sub-watershed 42   | 0.5                                                  | 0.49                                                     |
| 8  | Sub-watershed 44   | 0.98                                                 | 0.97                                                     |
| 9  | Sub-watershed 49   | 1.06                                                 | 1.04                                                     |
| 10 | Sub-watershed 56   | 0.4                                                  | 0.38                                                     |
| 11 | Sub-watershed 58   | 0.69                                                 | 0.66                                                     |
| 12 | Sub-watershed 59   | 1.1                                                  | 1.08                                                     |
| 13 | Sub-watershed 61   | 1.14                                                 | 1.13                                                     |
| 14 | Sub-watershed 62   | 0.81                                                 | 0.76                                                     |
| 15 | Sub-watershed 64   | 1.99                                                 | 1.95                                                     |
| 16 | Sub-watershed 68   | 2.03                                                 | 2.05                                                     |
| 17 | Sub-watershed 70   | 2.1                                                  | 2.12                                                     |
| 18 | Sub-watershed 72   | 2.16                                                 | 2.14                                                     |
| 19 | Sub-watershed 73   | 2.18                                                 | 2.14                                                     |
| 20 | Sub-watershed 75   | 2.21                                                 | 2.17                                                     |
| 21 | Sub-watershed 77   | 2.22                                                 | 2.18                                                     |
| 22 | Sub-watershed 81   | 2.25                                                 | 2.21                                                     |

The number of water discharge in each Sub-watershed was obtained from the output of SWAT modeling based on the 2015 land cover and spatial pattern planning input. These data were compared in order to see the difference in minimum water discharge of potentially sub-watershed, as shown in Table 5. It shows that the minimum water discharge is higher in land cover input in 2015 compared to the spatial plan. After the implementation of spatial patterns, there is one sub-watershed that do not meet the minimum water discharge is sub-watershed 32. So that the number of sub-watersheds in spatial pattern inputs generated only 21 sub-watersheds while in 2015 land cover input, there are 22 potential sub-watersheds.

The difference is caused by the influence of land cover conditions in each sub-watershed. It shows that the implementation of spatial planning made by local government can reduce the number of potential watersheds in the development of micro-hydro. So, it needs to be reviewed so that the adoption of spatial patterns can increase water flow and potential location for micro-hydro.

3.8. Calibration

The calibration used in this study is manual calibration with the coefficient of determination model. Calibration is done by comparing the model discharges with the actual discharges from 2004-2011, as shown in Figure 6.
Figure 6. Calibration of Discharge

From the comparison of actual water discharge and model, water discharge obtained the coefficient of determination (R²) is 0.8577. The number of R² lies between 0 - 1, and the suitability of the model is said to be better if R² gets closer to 1. So, the results of the model water discharge data can be accepted as the reference in further analysis.

3.9. Potential Power for Electricity Needs of The Community

The potential power generated by each sub-watershed was obtained by using the water hydraulic power equation. The analysis results are micro-hydro potential data in watts, which is converted to kilowatts (kW). Potential in each sub-watershed has a different number because its influenced by the minimum water discharge (0.3 m³/s) that flows into the turbine with the minimum waterfall height is 3 meters.

The availability of power generated by the Micro Hydro Power Plant in each sub-watershed, it can be calculated how many householders will receive new electricity supply with the minimum amount of electricity needed in rural areas. Calculation of the number of houses that will receive electricity supply is to divide the power generated by the minimum electricity requirements in watts, which is assumed to use 100 watts of electricity per house. Data on the number of houses that have electricity, as shown in Table 6.

| No  | Sub-watershed | Minimum Power (kW) | Number of Households served | Minimum Power (kW) | Spatial Pattern | Number of Households served | Deviation (kW) |
|-----|---------------|--------------------|----------------------------|--------------------|----------------|----------------------------|----------------|
| 1   | Sub-watershed 81 | 46.39              | 464                        | 45.53              |                | 455                        | -0.86          |
| 2   | Sub-watershed 77 | 45.61              | 456                        | 44.78              |                | 448                        | -0.83          |
| 3   | Sub-watershed 75 | 45.57              | 456                        | 44.74              |                | 447                        | -0.83          |
| 4   | Sub-watershed 73 | 44.96              | 450                        | 44.13              |                | 441                        | -0.83          |
| No | Sub-watershed | Minimum Power (kW) Land Cover | Number of Households served | Minimum Power (kW) Spatial Pattern | Number of Households served | Deviation (kW) |
|----|---------------|------------------------------|----------------------------|-----------------------------------|----------------------------|---------------|
| 5  | Sub-watershed 72 | 44.49 | 445 | 43.63 | 436 | -0.86 |
| 6  | Sub-watershed 70 | 43.24 | 432 | 42.32 | 423 | -0.92 |
| 7  | Sub-watershed 68 | 41.7 | 417 | 40.81 | 408 | -0.89 |
| 8  | Sub-watershed 64 | 40.97 | 410 | 40.09 | 401 | -0.88 |
| 9  | Sub-watershed 61 | 23.5 | 235 | 23.17 | 232 | -0.33 |
| 10 | Sub-watershed 59 | 22.56 | 226 | 22.24 | 222 | -0.32 |
| 11 | Sub-watershed 49 | 21.8 | 218 | 21.46 | 215 | -0.34 |
| 12 | Sub-watershed 44 | 20.21 | 202 | 19.88 | 199 | -0.33 |
| 13 | Sub-watershed 42 | 16.6 | 166 | 15.7 | 157 | -0.9 |
| 14 | Sub-watershed 58 | 14.21 | 142 | 13.64 | 136 | -0.57 |
| 15 | Sub-watershed 42 | 10.39 | 104 | 10.07 | 101 | -0.32 |
| 16 | Sub-watershed 38 | 10.23 | 102 | 9.91 | 99 | -0.32 |
| 17 | Sub-watershed 40 | 9.81 | 98 | 9.8 | 98 | 0.01 |
| 18 | Sub-watershed 56 | 8.25 | 82 | 7.92 | 79 | -0.33 |
| 19 | Sub-watershed 33 | 8.86 | 89 | 8.58 | 86 | -0.28 |
| 20 | Sub-watershed 23 | 8.23 | 82 | 8.25 | 83 | 0.02 |
| 21 | Sub-watershed 20 | 7.5 | 75 | 7.53 | 75 | 0.03 |

The minimum power of land cover in 2015 of most potential sub-watersheds is higher than the spatial pattern. By the implementation of the spatial pattern, there will be nine households that cannot be supplied with electricity on a certain day, assuming one household is equal to 1 house. But at Sub-watershed 20 and 23, the minimum power of spatial pattern is higher and not much different from the land cover in 2015. Sub-watershed, which produces relatively stable power and above 10 kW is found in sub-watershed 42, 44, 49, and 61 with consideration of the number of households supplied by electricity.
3.10. Watershed recommendations
With 2015 land cover conditions, not all watersheds can be recommended for Micro Hydro Power Plants. That is because there are several stages to obtain the micro-hydro potential in Kelara watershed, including the measurement of the height of the waterfall (head) and analysis of water discharge. So that the recommended watershed to be used as Micro Hydro Power Plant that produces power above 10 kW as in Table 7.

| No | Sub DAS     | District  | Regency |
|----|-------------|-----------|---------|
| 1  | Sub DAS 38  | Bontolempangan | Gowa    |
|    |             | Tompobulu   | Gowa    |
| 2  | Sub DAS 42  | Bontolempangan | Gowa    |
|    |             | Tompobulu   | Gowa    |
|    |             | Biringbulu  | Gowa    |
| 3  | Sub DAS 44  | Bontolempangan | Gowa    |
|    |             | Tompobulu   | Gowa    |
|    |             | Biringbulu  | Gowa    |
| 4  | Sub DAS 49  | Bontolempangan | Gowa    |
|    |             | Tompobulu   | Gowa    |
|    |             | Kelara      | Jeneponto |
| 5  | Sub DAS 58  | Rumbia      | Jeneponto |
|    |             | Tompobulu   | Gowa    |
|    |             | Biringbulu  | Gowa    |
| 6  | Sub DAS 59  | Biringbulu  | Gowa    |
|    |             | Tompobulu   | Gowa    |
| 7  | Sub DAS 61  | Biringbulu  | Gowa    |
|    |             | Tompobulu   | Gowa    |
|    |             | Biringbulu  | Gowa    |
| 8  | Sub DAS 62  | Kelara      | Jeneponto |
|    |             | Tompobulu   | Gowa    |
|    |             | Biringbulu  | Gowa    |
| 9  | Sub DAS 64  | Kelara      | Jeneponto |
|    |             | Tompobulu   | Gowa    |
|    |             | Biringbulu  | Gowa    |
| 10 | Sub DAS 68  | Kelara      | Jeneponto |
|    |             | Turatea     | Jeneponto |
|    |             | Biringbulu  | Gowa    |
| 11 | Sub DAS 70  | Turatea     | Jeneponto |
|    |             | Biringbulu  | Gowa    |
| 12 | Sub DAS 72  | Biringbulu  | Gowa    |
|    |             | Turatea     | Jeneponto |

In determining the potential sub-watershed, the power generated a minimum of 10 kW, watershed morphology, and changes in land cover are the consideration used. The Sub-Watershed, which located
downstream of Kelara watershed, is an allocated location as PLMTH that is allocated to be used more in areas that use more electricity than urban areas.

4. Conclusion
Based on the data and the results of the analysis conducted, then conclusions are generated based on the objectives of the study, which are as follows:

a. According to the condition of land cover in 2015, there are 22 potential sub-watersheds out of 83 sub-watersheds in Kelara watershed, which have the potential to develop micro-hydro. With the assumption of a minimum of 10 kW of power is generated at this time, there are 12 sub-watersheds that can be used for micro-hydropower plants.

b. The implementation of the spatial pattern plan in 2031 can reduce the number of potential sub-watershed based on the minimum debit. According to the 2015 land cover condition, there are 22 sub-watersheds, while in the spatial plan, there are 21 potential sub-watersheds.

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