Water balance evaluation in Penanggungan hamlet Wanayasa sub district Banjarnegara, district Central Java province

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Abstract. A key issue of watershed management in Indonesia is massive forest conversion in the upstream area. Forest conversion to agricultural land occurred in the Merawu watershed. Penanggungan Hamlet located in the upstream area of Merawu watershed, where the economic resources is potato (Solanum tuberosum L) farming. The agricultural and domestic water needs are supplied by 5 springs water in the surrounding areas. Intensive farming needs a large portion of water. Inefficient water utilization pattern and the El Nino phenomena may raise water competition among agricultural and domestic sectors in Penanggungan. Deficit water was occurred in the Penanggungan Hamlet, particularly in the dry session. The purpose of this study is to evaluate the water availability based on regional water balance and design the drought mitigation. Regional water balance focused in terms of demand and supply. The water demand covers daily household needs such as cooking, bathing, toilet, washing dishes, laundry, cleaning the floor, washing vehicles, watering yards, and drinking. The demand likewise comes from farming sectors for irrigation and pesticide application. The demand calculated for one year. A water need census in Penanggungan was conducted to acquire data on the amount of water per sector. Water supply calculated from the discharge of 5 springs for one year. Prediction of water needs used three parameters i.e., population, total household and agricultural water needs. This study reveals that the water demand in Penanggungan Hamlet is surplus until 2031 but in 2032 until then it experiences a deficit.

1. Introduction

Water is the most important element in every living thing on earth. Scientifically, water is a chemical compound that results from the bond between oxygen (O₂) and hydrogen (H) which then forms a water compound (H₂O). This is the most common compound found on earth, reaching 71% [1]. Water comes from the surface of the earth and below the surface. Surface water is water that is located above ground levels such as rivers, lakes, reservoirs, and swamps. Whereas groundwater is located below the surface of the ground like rainwater that falls then seeps into the ground. Water that exists on this earth either surface or groundwater is due to the hydrological cycle.

The hydrological cycle naturally occurs in a watershed area. The amount of water flow in a watershed or catchment area can be predicted using the water balance approach. [2] argues that the water balance is an illustration of the distribution of water according to the prevailing water system in
a watershed. The results of the water balance analysis can be used to determine whether the amount of water has a surplus or has a deficit. The Serayu watershed is one of the largest watersheds on Java Island located in the central part of the island. This watershed covers several districts in Central Java Province, namely Wonosobo, Banjarneagara, Purbalingga, Banyumas, and Cilacap. The Serayu watershed has suffered environmental damage and pollution resulting in a decrease in the quality and quantity of the Serayu river water.

The influential components for calculating water balance are irrigation water needs and water needs for RKI (household, urban, industrial, and fisheries). The RKI component is closely related to the rate of population growth. The more population, the need will increase as well. At one time there will be a condition of lack of water because the available water does not meet the needs of the community. This can be predicted by the water balance approach. The watershed is divided into 3 parts, namely upstream, middle, downstream. The upstream part of the watershed is an area with a protected function, especially for the protection of the water system, which is important for other parts of the watershed [3].

The Merawu watershed is one part of the upstream Serayu watershed located in Banjarneagara Regency. Penganggungan Hamlet is one of the hamlets located in Penanggunan Village. The Penanggunan population in 2018 is 447 people. Almost all of the underprivileged people work as farmers. The main commodities are potatoes (Solanum tuberosum L), chili (Capsicum annum L), cabbage (Brassica oleracea), carrots (Daucus carota L), and leek (Allium fistulosum).

According to [3], the upstream area is characterized as a conservation area, has a high drainage density, a large slope (> 15%) is not a flood area, water use is determined by drainage patterns and the type of vegetation is generally a forest stand. While in reality the upstream of the Merawu watershed, especially in Penanggunan Hamlet, most of them have turned into intensive agricultural areas. Instead, the function of forest land into intensive agriculture will have an impact on hydrological functions such as water management and water flow in an area. This condition will affect water balance in the area where the fulfillment of food needs and activities of the population is always closely related to water needs.

The water needs of the Penanggunan Hamlet community are met from springs. Penanggunan residents report 5 springs found inside forest areas and agricultural land. This spring is used by the community to meet non-domestic (agricultural) and domestic (daily) needs. Agriculture requires water for maintenance activities including watering and spraying pesticides. In 2015 the water demand for the agricultural sector began to be unfulfilled, this was due to the less efficient pattern of community water utilization and coincided with the El Nino phenomenon that occurred in several regions in Indonesia including Java. There is no study on the water balance in the Penanggunan Hamlet so that this research is focused on knowing the availability and consumption of water. The results of this study are expected to provide information about the current and future water balance.

2. Methods
2.1 Location
This research was conducted in Penanggungan Hamlet in the upper part of the Merawu watershed in the Serayu Watershed. Administratively, the research location is in Penanggungan Village, Wanayasa Subdistrict, Banjarnegara Regency.

The research period is divided into pre-field, field data collection, and post-field. Pre-research includes survey activities to the location of research and activities that have been literature. The data collection stage and post-field stage include data analysis.

2.2 Data
The data sources used in this study consist of:
1. Primary data, namely data obtained directly from the field. Primary data from the field in this study include:
   - Springs discharge data from 5 springs found in Penanggungan Hamlet
   - Data on water source utilization in Penanggungan Hamlet
2. Secondary data, namely data taken from several literatures, as well as from official parties related to direct recording or direct interviews, primary data from this study include:
   - Map of Penanggungan Hamlet
   - Administrative data covers the area and population of Penanggungan Hamlet

2.3 Data Collection

2.3.1 Identification Of Springs. Based on the results of interviews with the Penanggungan Hamlet community, hamlet water source information has been obtained.

Spring discharge
Measurement of spring discharge using the Volumetric method
Measuring spring water using the volumetric method is the simplest method, especially in small flows. The flow is inserted into a small vessel or measuring vessel and then recorded the time to fulfill it, so that the discharge is obtained.

\[
\frac{V}{T}
\]  \text{ (1)}

Measurement of 5 springs using the volumetric method.

2.3.2. Analysis Of Water Needs. At this stage a survey and questionnaire are filled out by respondents. In this study, respondents were all residents spread in Penanggungan Village. The questionnaire given to respondents was conducted to obtain data on the number of residents who use water for daily household needs such as bathing, drinking, washing and non-domestic needs such as agriculture. The respondent unit is the Head of Family. To find out the amount of water requirements from interviews and questionnaires collected and analyzed.

- Calculate domestic water needs
  \[\text{Total water needs} = \text{Total Population} \times \text{Water needs} \text{ l/capita/day} \]  \text{ (2)}
- Calculate non-domestic water needs which include agriculture
- Calculating total water needs
  \[\text{Total water needs} = \text{Domestic water needs} \times \text{Non domestic water needs} \]  \text{ (3)}
- Predict the population projected for the next 20 years using geometric methods
  \[P_n = \text{number of population in year } n\]
  \[P_0 = \text{number of residents in the initial year}\]
  \[r = \text{Percentage of population growth}\]
  \[n = \text{time period in } n\]

2.3.3. Water Balance. The status of the analysis of the status of the carrying capacity of the water balance-based environment is indicated by a comparison between the conditions of water availability in an area condition and the existing needs. From the comparison of the two, a condition of water availability is obtained in the region. Water DDL status criteria are stated with a water balance surplus deficit.

\[\text{Neraca} = \text{Q_ketersediaan} - \text{Q_kebutuhan} \]  \text{ (4)}

Information:
- \(Q_{availability}\) : availability of water
- \(Q_{requirement}\) : requirement Water Requirement
The amount of water availability in the Penanggungan Hamlet is known from the calculation of spring discharge. Domestic and non-domestic (agricultural) water needs are obtained based on direct surveys to the community. Evaluation is carried out to observe / observe patterns of water use by the community in the past from 2018 to be able to predict the next 20 years. Predictions are carried out for the next 20 years based on changes in the area. To predict the need of the community for the next 20 years, data on the rate of growth of the population of Penanggungan Hamlet is needed. Predicting the rate of growth of the community using geometry methods which can be seen in Equation (5).

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P_n = P_0 (1 + r)^n 
\]

\( P_n \) = Total population in the n year
\( P_0 \) = Total population at the beginning of the year
\( r \) = Projection time period
\( n \) = The average percentage of population growth per year

3. Result
Administratively, Penanggungan Hamlet includes Penanggungan Village, Wanayasa Subdistrict, Banjarnegara Regency. The hamlet area is 140 ha or 33% of the total village area. Based on data obtained from the Village office, the total population of Penanggungan in 2018 was 447 people consisting of 105 households. Most of the people work as farmers, farm laborers and students.

3.1. Water Availability In Penanggungan Hamlet
In meeting clean water needs, the community uses springs as their source of clean water. Among them are 4 points of springs found on community farms and one of the largest springs in the forest area. The utilization of springs in Penanggungan Village is still done easily, namely 5 points of the spring are first flowed to the reservoir and then flowed through the pipes to the houses. The maintenance of springs is carried out voluntarily by the community who take part in utilizing the spring. Maintenance is carried out such as cleaning the tree-branch rating that blocks the reservoir and repairs to facilities such as main pipes and drain pipes that are connected directly to people's homes. The results of the discharge measurements of each spring are presented in Table 1.

| Mata Air | l/second | l/minute | l/hour | l/day | l/year |
|----------|----------|----------|--------|-------|--------|
| 1        | 0.31     | 18.75    | 1.125  | 27.000 | 9.855.000 |
| 2        | 0.83     | 49.8     | 2.988  | 71.712 | 26.174.880 |
| 3        | 0.83     | 49.8     | 2.988  | 71.712 | 26.174.880 |
| 4        | 1.25     | 75       | 4.500  | 108.000 | 39.420.000 |
| 5        | 1.25     | 75       | 4.500  | 108.000 | 39.420.000 |

Availability debit 141.044.760

Source: researcher, 2019
3.2. Water Needs

3.2.1. Domestic Water Needs. Fulfilling the domestic water needs of the community Penanggungan uses several water sources found both in the forest and agricultural areas. From the results of an interview survey of the local community, to fulfill the daily needs of the community using from 5 springs, where 4 sources of springs are located in the agricultural area and 1 source of springs is in the forest area.

Domestic needs (daily) include, cooking, bathing, latrines, washing dishes, washing clothes, drinking, etc. Some sources of springs are accommodated in reservoirs and then channeled directly through the pipeline to the houses. The interview results of water needs are known that on average in 1 house is occupied by 2 - 8 people and for the average daily water needs in Penanggungan Hamlet for domestic needs is 93.53 l/soul/day. The results of observations and direct interviews with the community related to the size of the domestic water needs of the people in the penanggungan hamlet can be seen in the Figure 3.
The total of domestic water needs (daily) in Penanggungan Hamlet is 93.53 l/person/day by the standard water requirements. The standard of water requirements by the standards determined by Pupr presented in table 2.4 explains that the population of <20,000 standard water requirements is 60-90 l/person/day. The amount of water demand in an area is determined by several factors such as age, number of family members, customs/habits, availability of water resources.

3.2.2. Non Domestic Water Needs. Non-domestic water needs include agriculture, to meet agricultural water needs such as watering and spraying pesticides the community takes water from the five local springs. Spraying activities both for watering and spraying pesticides in the dry season are carried out two to three times a week depending on each farmer.

The volume of water requirements for the agricultural sector will be different for each household, in addition to being measured from different land areas and the capital of farmers to spray. The land area of 0.25 ha for a single watering activity ranging from ± 7 hours a day. While for spraying pesticides depends on the area of land and commodity crops to be sprayed. The area of 0.25 ha requires ± 200 - 300 l for one spraying activity.

The Penanggungan Hamlet community cultivates a variety of crop commodities with the main commodities of potatoes and intermediate commodities such as cabbage, chili, carrots and leek. The Penanggungan Hamlet community uses alternating planting patterns in each planting season. As well
as resting the land after the harvest season which aims to reduce land stress levels so as not to reduce land productivity. Tabulation results from observations and interviews can be seen in the Table 2.

| Time                | Community activities | Sprinkling (l/ha) | Spraying pesticides (l/ha) |
|---------------------|----------------------|-------------------|---------------------------|
| Total (Days)        |                      | 2.588             | 232                       |
| Total (Weekly)      |                      | 18.122            | 1.622                     |
| Total (Monthly)     |                      | 72.487            | 6.488                     |
| Total (years)       |                      | 869.840           | 77.861                    |
| Total (l/years)     |                      |                   | 947.701                   |

*Source: researcher, 2019*

### 3.3. Water Balance

Water needs in an area are influenced by the number of people in the area. Penanggungan Hamlet is one of the hamlets that has a population growth every year, although population growth does not occur significantly. Conditions of water availability in an area condition with existing needs. From the comparison of the two, a condition of water availability is obtained in the region. Analysis of resource availability in this study includes the availability of surface water. This analysis of water availability is basically done to determine the quantity of various water availability in this study area. The community growth rate is calculated using geometric methods. The results of the growth rate analysis of the Penanggungan Hamlet community for the next 20. From the analysis of projections of population growth in Penanggungan Hamlet, it can be seen that population growth in Hamlets increases with a percentage of 0.0080% with an annual population increase. Amounting to 4 people. So that it can be stated that population growth affect water needs in this research area. Increasingly increasing population every year also increases the demand for clean water for various community activities in the Penanggungan Hamlet.

![Figure 5. Graph of Projected Population.](image)
Figure 6. Graph of Water Requirements

In Figure 6, it can be seen that the rate of population growth and water demand continues to increase with increasing years. The total water demand in 2018 is 76,955,247.15 l/year. In 2038 the population reached 2,365 people with a total water requirement of 488,862,251.25 l/year. From the results of the water balance analysis, it can be seen in Figure 6 that the water balance condition in Penanggungan Hamlet from 2018 to 2031 is still in a surplus condition, where water availability is greater than the community’s water needs. In 2032 until 2038 the water balance in Penanggungan Hamlet was in a state of deficit because the community's water needs were greater than the availability of water in the area.

The need for water will increasingly increase in line with the increasing needs of human life in both urban and rural areas. The increase in water demand in Penanggungan Hamlet which is increasing rapidly makes the water balance condition in the region suffer deficits. According to [3] the upstream watershed is based on a conservation function that is managed to maintain the watershed's environmental conditions so as not to be degraded. The conservation function can be indicated by the condition of watershed land cover vegetation, water quality, the ability to store water (discharge) and rainfall. The upstream area of the watershed which was originally a protected area has largely been converted into an intensive agricultural area. Changes in functions in the region cause various changes including the availability of water.

The upstream area of the watershed generally has many sources of water that can be used by the community for various daily activities. The sustainability of water will be maintained if it is supported by environmental factors and human activities. The availability of water in the upstream area of the Merawu watershed, especially in Penanggungan Hamlet, can only fulfill community water needs until 2032 where the upstream area of the watershed is not a drought area and in the history of Penanggungan Hamlet has never experienced a drought. The growth rate of the community and community water needs has caused the availability of water in Penanggungan Hamlet unable to meet the water needs in the area. Water needs for agriculture are still stable if the Penanggungan Hamlet community still maintains a maintenance pattern (watering and spraying) as it is today. The balance of the water balance will be maintained if the community carries out an efficient water utilization pattern.

The evaluation was carried out to observe / observe patterns of water use by people from the past to predict the next 20 years that expected changes had occurred in that location. Predicting the next 20 years will be done by projecting future needs. The water balance condition for 2018 until 2031 is still in a surplus condition so that it can be interpreted that the availability of water for the underwriting hamlets is still fulfilled. The water balance condition in Penanggungan has a deficit from 2032 to 2038 where the availability of being unable to meet the increasing water needs of the community is presented in Figure 6.
Penanggungan Hamlet, the majority of which are farmers. This causes water requirements for agriculture to be classified as very large compared to domestic water needs. The amount of agricultural water needs is based on plant commodities cultivated by the community. The water requirements for each plant are different. Water needs for agriculture/irrigation are the amount of water volume needed to meet the needs of evapotranspiration, water loss, water requirements for plants by taking into account the amount of water supplied by nature through rain and groundwater contributions. Several factors affect plant water needs such as climate influence, characteristics of plants that are resistant or not to pests, so that they require additional special treatments such as spraying and plants that require a lot of water.

In 2015 farmers in Penanggungan Hamlet experienced a shortage of water to meet agricultural needs. Water shortages that occur may be caused by the El Nino phenomenon and commodities being developed by farmers. This evaluation was conducted to find out various factors that influence the pattern of water use by the community so that it can be used as a basis for mitigation directions to prevent water shortages in Penanggungan Hamlet. In addition to the results of the water balance tabulation, data on changes in water use patterns are also needed in the past to see changes in water use patterns.

From the results of interviews with the local Village Head, information was obtained that an increase in water demand for the agricultural sector was related to the pattern of water use by the community. In the 1980s the main commodity in Penanggungan Hamlet was tea, in this era the yield from tea plantations was still promising and the water needs for the agricultural sector were still sufficient. Entering the early 1990s the community began to add other commodities in the form of tobacco plants while maintaining a portion of existing tea plantations, in this era the selling value of tobacco was promising so that people began to switch to tobacco commodities. For water needs in the 1990s it was still sufficient.

Entering the 2000s the local community began using intercropping patterns with cabbage plants but were not used as the main commodity because the productivity of tea and tobacco was still in a good category. In 2005 the community slowly began to shift to potato commodities. The change was due to the progress of potato cultivation in Dieng and the high selling value of potatoes at that time so that people began to study in Dieng to cultivate potatoes and apply in Penanggungan Hamlet. Interspersed by several other crop commodities such as cabbages, carrots, chilies, snouts using intercropping patterns.

In 2010, potatoes have been used as the main commodity by the community due to high productivity and high selling value. Until 2010, water needs were still sufficient. Entering 2015, there was a water crisis for the maintenance of community agricultural crops, due to the inefficient use of water by the community, especially when spraying on a large scale and simultaneously so that the discharge of water was not sufficient for spraying activities.

The water crisis that occurred in the Penanggungan Hamlet coincided with the occurrence of the El Nino phenomenon which caused long droughts in several regions in Indonesia. Regions in Indonesia that are potentially affected by the 2015 El Nino include South Sumatra, Lampung, Java, Bali, Nusa Tenggara, South Kalimantan (South Kalimantan), and South Sulawesi. The El Nino phenomenon that affects the length of the 2015 drought can subsequently lead to the decline of the 2015/2016 rainy season in some regions. This then has an impact on the length of famine or crop failure, especially in the agricultural sector.

From the results of interviews with farmers since 2016, until now there has been a decline in potato productivity. This is likely due to the decrease in the productivity of the land itself due to more than proper spraying activities. Until now, the community is still thinking of replacing other commodities that have high selling value such as potatoes. Judging from the early history of change in Penanggungan Hamlet, it can be stated that the amount of water demand, especially non-domestic, is influenced by changes in commodities cultivated by the community. Changes in commodities will affect the pattern of water use by the community.
According to [3] upstream areas are characterized as conservation areas, have high drainage density, slope of (> 15%), are not flooded areas, water use is determined by drainage patterns and vegetation types are generally forest stands. Whereas in reality and the history of change in the Penanggungan hamlet, the function has turned into intensive agriculture and has developed along with the increasing needs of the community. Since the water crisis and the decline in potato productivity, the community has slowly begun to realize the importance of water so that people begin to use water efficiently.

4. Conclusion
1. Community water needs come from 5 springs. The biggest supply of springs is in springs D and E.
2. The average domestic water demand of Penanggungan community has exceeded the standard. While for non-domestic water needs the largest volume allocation is watering activities.
3. Water demand increases with increasing population growth. The water balance condition in Penanggungan hamlets in 2018 to 2031 is in a surplus condition, while in 2032 to 2038 in a deficit condition.

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