Water Availability In Patuha Mountain Region Using InVEST Model "Hydropower Water Yield"

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Abstract. The mountainous region provides ecosystem services for the surrounding area and its lowland area. Patuha Mountain Region located in Ciwidey, Rancabali and Pasirjambu district of Bandung Regency. Fast population growth causing the need for water to increase drastically. The water yield from an ecosystem or watershed can be estimated using a hydrological model. This study aimed to estimate water yield, both the magnitude and their spatial distribution of the Patuha Mountain catchment areas. The water yield from the study area was calculated using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) water yield model, which based on the water balance approach. The results indicated that the volume of water yield in Patuha Mountain for 2018 has a value between 21.429 to 31.857 m^3/ha/year and approximately 1.202 million m^3 per year. Spatially, sub-watersheds with a high volume of Water yield located in the southeast of Patuha Mountain, which is a mountainous area with an elevation of more than 1.500 m above sea level and rainfall average of 2.500 to 3300 mm per year. The water yield area also shows the same pattern with the distribution of the rainfall area.

Keywords: **Patuha Mountain; Water Yield; InVEST; Rainfall; Sub-watershed.**

1 Introduction

Mountainous regions in Java expressed as an area above 1.000 meters above sea level [1]. The mountainous region provides ecosystem services for the surrounding area and also the lowlands. One of the ecosystem services in the mountainous region is water provision services. Mountainous areas are acting as water towers or water sources to meet domestic, industrial, irrigation, and other water needs [2]. The Patuha Mountain region, which located in the administrative area of Bandung Regency, is upstream of the Citarum, Cibuni, Cisadea, Cipandak, Cidamar and Cilaki Watersheds. Patuha Mountain is also the primary water catchment area in Bandung Regency based on the Bandung Regency Regional Spatial Planning map for 2007-2027.

Therefore, the existence of forests in a sufficient extent and excellent conditions in an area is essential to be maintained to avoid droughts and floods. The fact is that forests in the upper area of the Citarum watershed have dropped from 35.000 ha in 1992, to 19.000 ha in 2001 (a 45% reduction), this reduction caused by the expansion of dryland agricultural areas [3]. If the forest area decreases, and the agriculture area increases, the water yield in the area will decrease [4].

Concrete steps need to be taken to protect water catchment areas and prevent water yield depletion in the Patuha Mountain area. To maintain the water provision ecosystem services, we need to estimate the quantity of water availability and its distribution, then measure the level of carrying capacity of water on Mount Patuha related to meet the community's need for water.

In the era of technological revolution 4.0 as it is now, where the integration of the use of technology and the internet is so sophisticated and massive, analysis of the availability of water in an area should be easily carried out. There have been many methods and software for researching water availability such as the Mock, National Rural Electric Cooperative Association (NRECA) [5] and Soil Water Assessment Tool (SWAT) applications [6], but the Mock and NRECA methods still use conventional methods such as directly measuring on-site measurement so that it is impractical and its accuracy is very dependent on how to measure it. (Wealth Accounting and the Valuation of Ecosystem Services [7]. Meanwhile, SWAT applications that have widely used in Indonesia require many variables, and the data difficult to find in agencies in Indonesia especially online data. The need for data that is available online through the internet could make the water yield estimation more efficient by reducing the data collecting method in the fields.

The InVEST "Hydropower Water Yield" model is one of the Budyko water balance based water calculation methods. The water yield estimation method uses fewer variables and data compare to Mock, NRECA, and SWAT. The data used for The InVEST model are widely available online through internet data portals from various institutions [8].

This study aimed to estimate water yield, both the magnitude and their spatial distribution of the Patuha

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Mountain catchment areas using InVEST "Hydropower Water Yield" Model. The use of data that is available online through data portals for InVEST "Hydropower Water Yield" Model would make the estimation of water yield more efficient and in line with the spirit of the implementation of technological revolution 4.0.

2 Methods

2.1 Study Area

The research area located in the Patuha Mountain Area and its surroundings. The Patuha Mountain region is a mountainous region in the southwest part of Bandung Regency, West Java. The Patuha Mountain area has an area of 39,586 hectares. The area administratively divided into three districts. The district which has the largest area is Pasirjambu district with an area of 20.401 ha (50.8%). This district has ten villages. While the smallest district is Ciwidey district which is only 4,878 ha (12.3%) consisting of seven villages.

The elevation of Patuha Mountain and its surroundings ranging from 1.000 – 2.424 meters above sea level (masl). The average rainfall on Mount Patuha per year is 3.566 mm, where dry months occur in August to September, and the rest are wet months. The number of watersheds found in Patuha Mountain is 6 watersheds, namely Citarum watershed, Cilaki watershed, Cidamar watershed, Cipandak watershed, Cisadea watershed, and Cibuni watershed.

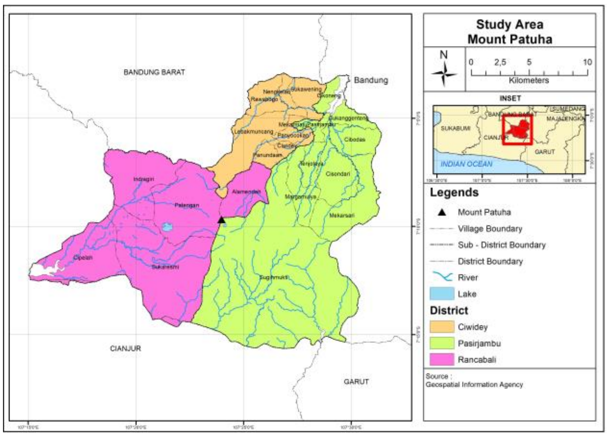

Fig 1. Study Area

2.2 Data

In analyzing the availability of water, base data needed are as follows: (1) soil type and texture (percent clay and percent sand); (2) capacity of water available for plants (cm/cm); (3) solum depth (mm); (4) land use/land cover (type of landuse); (5) root depth (mm); (6) plant coefficients (desimal number); (7) daily solar radiation (KWh/m^2); (8) minimum and maximum daily air temperatur (^{o}C); (9) daily rainfall (mm); (10) Zhang coefficient (integer number); (11) water content available for Plantation (integer number); (12) coefficient of water availability for Plantation (unit); (13) annual reference evapotranspiration (mm); and (14) Watershed / Sub-watershed Boundaries (line boundaries) [9].

Table 1. Data Source for InVEST Model "Hydropower Water Yield"

Variables	**Data**	**Source**	
		Online Data Portal	**Offline/Hardcopy**
Root restricting layer depth	Soil Depth	soilgrids.org	
	Root Depth	fao.org	
Precipitation	Annual precipitation	dataonline.bmkg.go.id (only in certain cities/districts)	The head office's meteorological climatology and geophysics agency
Plant Available Water Content	Percentage of clay and sand	soilgrids.org	
	Hydrology tools	Soil Plant Air Weather (SPAW) software that can be download in www.nrcs.usda.gov	
Average Annual Reference Evapotranspiration	Temperature data	dataonline.bmkg.go.id (only in certain cities / districts)	
Land use/land cover	Satellite imagery	earthexplorer.usgs.gov	
Watersheds	Watersheds boundary	appgis.dephut.go.id	
	Subwatersheds boundary	tides.big.go.id/DEMNAS/	
Biophysical Table	Crop Coefficient (KC)	fao.org	
	Root Depth		
Water Demand	Water consumption/day		Directorate General of Irrigation public Works Service

These data are challenging to obtain when using conventional methods such as measuring directly in the field, finding samples at the location or obtaining them from government agencies with complicated bureaucracies and often require a long time. The data needed by the InVEST model is not as much as the data needed by SWAT applications or others. Also, the data is easily available on the Internet such as government websites, organizations, or other online sources.

Furthermore, for daily and annual rainfall data obtained from the Meteorology, Climatology and Geophysics Agency, Bandung Regency of West Java Province. Data on soil types were obtained from the Soil Research Center on a scale of 1: 50.000. Available water capacity for plants is based on soil type and texture data using Soil Water Characteristics software developed by the USDA Agricultural Research Service in collaboration with the Department of Biological Systems Engineering, Washington State University [10]. Given the limitations of existing soil characteristics data, default values are used for other parameters (e.g. percentage of organic matter and salinity). More complete data sources for the InVEST model can be seen in Table 1.

Fig 2. Online Data Portal for InVEST Model

2.3 Processing Data

Based on the water yield model at InVEST, annual water yield for each pixel, (Y(x)), at a specific land cover in this study determined using Equation (1) [11]. Then, annual water yield classified into five classes using equal interval techniques on GIS software.

$$Y(x) = \left(1 - \frac{AET(x)}{P(x)}\right) \cdot P(x) \tag{1}$$

Where :

AET (x) = actual evapotranspiration for pixel x.
P (x) = annual rainfall at pixel x.

For vegetated land use or land cover, actual evapotranspiration values are calculated based on Budyko's water balance curve [12] as follows:

$$\frac{AET(x)}{P(x)} = 1 + \frac{PET(x)}{P(x)} - \left[1 + \left(\frac{PET(x)}{P(x)}\right)^{\omega}\right]^{\frac{1}{\omega}} \tag{2}$$

Where:
PET (x) = potential evapotranspiration for pixels
w = coefficient of water availability for plants [12].

Potential evapotranspiration, PET (x), is determined using Equation 3 [11].

$$PET(x) = ET_{0(x)} \times K_{c(x)} \tag{3}$$

Where:
ET0 (x) = reference evapotranspiration from pixel x
Kc (x) = plant coefficient (evapotranspiration) on pixels related to land use / closure.

The reference evapotranspiration reflects local climatic conditions based on the reference plant evapotranspiration at that location. Plant coefficient is mainly determined by vegetation characteristics (plant root depth and plant coefficient) of land cover/use in each pixel [13]. The coefficient of water availability for plants in each pixel, w (x), is calculated using Equation 4 developed by Donohue [14].

$$\omega_{(x)} = Z \times \frac{AWC_{(x)}}{P_{(x)}} + 1.25 \tag{4}$$

Where:
AWC (x) = volume (mm) of water content available for plants
Z = empirical constant (also called seasonality factor / Zhang coefficient) which reflects the local rainfall pattern and hydrogeological characteristics.

The value used in this study is 4, which is the recommended value for watersheds in the tropics [9]. The minimum value of w (x) is 1.25 which is the value of vacant land (root depth is 0) as suggested by Donohue [14], while the maximum value of w (x) is 5 [14, 15].

$$AWC_{(x)} = Min(Rest.layer.depth, root.depth) \cdot PAWC \tag{5}$$

AWC (x) determines the amount of water stored and released in the soil for use by plants. These parameters are estimated as a result of Plant Available Water Capacity (PAWC) and the minimum root-restricting layer depth and vegetation rooting depth as presented in Equation 5 [11].

Actual evapotranspiration for non-vegetation land use/cover (for example: water bodies, settlements) is calculated directly from reference evapotranspiration, namely ET0 (x), multiplied by evapotranspiration factors for each land use (Kc (x)) and has a specified upper limit by precipitation according to Equation 6 [11].

$$AET_{(x)} = Min\left(K_{c(x)} \times ET_{0(x)}, P_{(x)}\right) \tag{6}$$

The reference evapotranspiration (mm. Day-1), (ETo), is calculated using the modified Hargreaves equation (Equation 7), which gives better results than the Penman-Monteith method when the required data is limited [16]. The data needed in this equation are monthly precipitation data (P), maximum and minimum air temperature (Tmax and Tmin) and extraterrestrial radiation (Ra). August rainfall data is chosen because is the driest month or the least rainfall compared to other months of rainfall on Patuha Mountain.

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Rainfall data were then interpolated using the Kriging method to determine the value of rainfall on Mount Patuha as a whole. The Kriging method was chosen because it has the lowest deviation or standard deviation value compared to the IDW and Spline methods. Furthermore, this rainfall data is overlaid with air temperature data. The maximum and minimum air temperature data are interpolated respectively by the Kriging method. After obtaining the results of the second interpolation of the temperature, the two raster data are converted into vector data for further overlaying. This overlay is intended to measure the value of the average temperature in the Patuha Mountain region and the difference in air temperature between the two temperatures. The results of the two calculations are included in the Hargeaves equation.

$$ET_{(0)} = 0.0013 \times 0.408 \times Ra \times \left[\left(\frac{Tmax + Tmin}{2}\right) + 17\right] \times [(Tmax - Tmin) - 0.0123P]^{0.76} \quad (7)$$

Where :
Ra = Extra-terrestrial solar radiation (MJ.m-2 days-1)
Tmax = maximum daily average air temperature (oC)
Tmin = average minimum daily air temperature (oC)
P = monthly rainfall (mm.month-1).

From these equations, the InVEST water yield model calculates potential evapotranspiration, actual evapotranspiration, and annual water yield. Explanation about the calculation of the InVEST model can be seen in the flowchart in Fig. 2. Water requirements for agriculture in the Patuha Mountain Region are derived from the standard of water requirements for plants according to the Food and Agricultural Organization (FAO). Water requirements for plants have units of mm/day. For this reason, the unit needs to be converted to $m^{3/}$year. To find out the total water requirements in a sub-watershed, the area of each land use must be calculated first in hectares. Then, the water requirements for plants will be multiplied by the land use per sub-watershed to determine the total water requirements for agriculture in the sub-watershed.

Then for domestic water needs, including bathing, drinking, and washing, it will be calculated in units of m^3/hectare/year. The number of people in one hectare is known from the total population density divided by the area of settlements in units of hectares. The analysis used in this study is spatial descriptive analysis, by explaining the conditions of water availability in each sub-watershed and explain the spatial variation of water availability in the Patuha Mountain region which has been produced by the InVEST model. After the results of the calculation of water availability and water requirements are obtained, the existing data is used as a table for comparison. If water availability is greater than water demand, then the carrying capacity of water in the region is surplus. If water availability is smaller than water needs, then the carrying capacity of water is depleted.

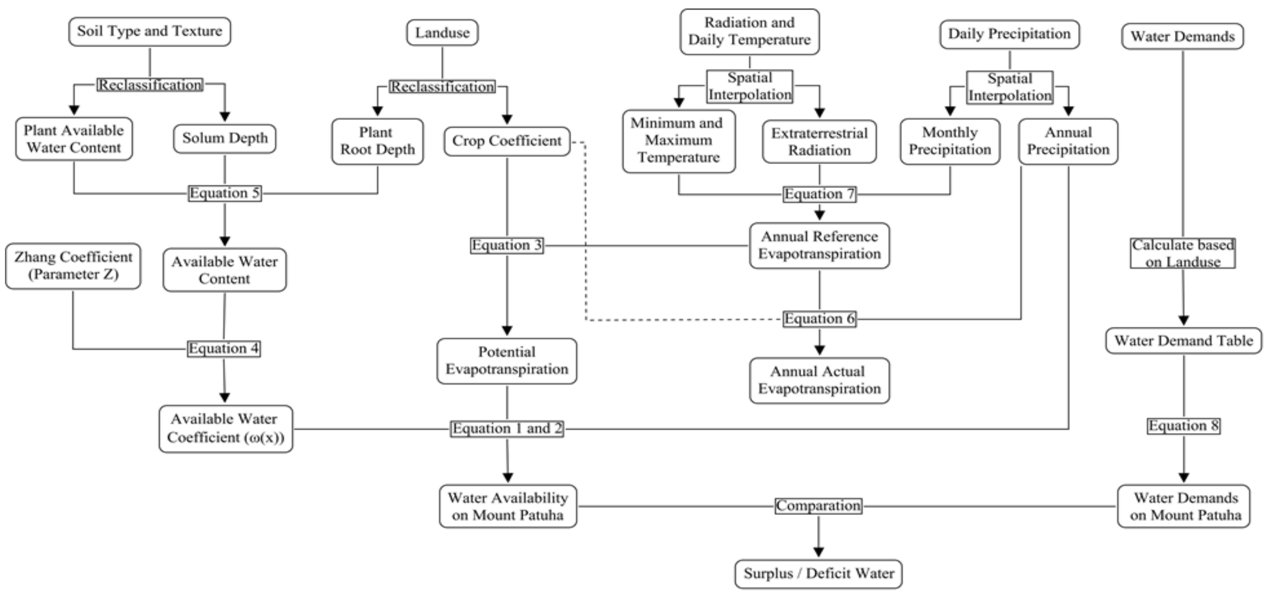

Fig 3. Research Workflow

3 Result and Discussion

3.1 Water Supply Coefficient for Plants (ω (x))

Water Supply Coefficient Value for Plants or ω (x) is obtained by knowing the Zhang coefficient value and Water Supply Volume for Plants (AWC (x)). The Zhang coefficient is a Z parameter or a season factor that reflects the local rainfall pattern and hydrogeological characteristics. Zhang's coefficient in this study is 4, which is the recommended value for watersheds in the tropics [9, 17]. Meanwhile, AWC (x) is produced from the depth of plant roots and the value of Plant Water Availability Capacity (PAWC).

The root depth of plants is defined as how deep the roots can be planted into the soil without being obstructed. Each vegetation has a different root depth.

Primary forests, secondary forests, and plantations are classified into forest land uses. While dryland agricultural land use and mixed dryland agriculture will be divided into lowland agricultural land (600 - 1500m) and upland agriculture (> 1500m). This distinction is made considering that agriculture in the lowlands and highlands has different characteristics of irrigation and planting techniques [18].

The root depth value of each vegetation is based on the Food and Agricultural Organization (FAO). Vegetables such as chili, cabbage, cabbage, tomatoes, and rice and grass have fiber-type roots that are generally relatively shallow, only in the range of 300 - 600 mm. Tea plants have a depth of 900 mm with taproots. While forest vegetation in such as *Pinus Merkusii*, *Altingia excelsa Noronha*, *Schima walichii* and others have deep roots, namely > 1.000 mm. The root depth of each land use can be seen in Table 2.

Table 2. Root Depth of Different Types of Land Use

No.	Landuse	Root Depth (mm)
1	Water Bodies	0
2	Shrubs	600
3	Paddy Field	500
4	Lowland Agriculture	700
5	Highland Agriculture	550
6	Settlements	0
7	Tea Plantations	900
8	Forest	1100

Source : [19]

It can be seen in Table 2 that the three types of soil textures namely Loam, Clay Loam, and Clay have PAWC values in the same range of 0.12 to 0.15. This is because the three textures do have characteristics of sand and clay which differ only slightly, so the PAWC value depends only on the combination of clay and sand. For more details, the PAWC value for each soil texture is presented in Table 3.

Table 3. Plant Available Water Content Based on Soil Texture

Soil Texture	Contents		
	Clay (%)	Sand (%)	PAWC
Loam	26 -27	41 - 43	0,12
	23 - 27	36 - 41	0,13
	24 - 27	30 - 35	0,14
Clay Loam	28 - 38	37 - 43	0,12
	28 - 39	28 - 37	0,13
	28 - 39	24 - 34	0,14
	31 - 32	24 - 26	0,15
Clay	40 - 47	23 - 34	0,13
	40 - 44	23 - 27	0,14

Source: Personal Data Processing

The content of water availability is the volume of water available for plants whose value depends on the fraction of the availability of water for plants with the depth of the roots of each plant. The lowest AWC value is located in low-lying areas such as Ciwidey and the northern part of Pasirjambu. Low AWC value is because the vegetation planted in the lowlands is vegetables, rice which has shallow plant roots (<900 mm). While in the highlands such as Rancabali and Pasirjambu in the middle and south, the AWC value is high. Because in that area the dominating vegetation is forest and tea plantations which have deep root depths (> 900 mm). Thus, the root depth factor is a determining factor in the amount of water availability (AWC).

3.2 Average Annual Potential Evapotranspiration (PET)

Potential evapotranspiration is a value that describes the needs of the environment, a set of vegetation, or an agricultural area to evapotranspiration determined by several factors, such as the intensity of solar radiation, wind speed, leaf area, air temperature, and air pressure. Potential evapotranspiration is how much evapotranspiration is released by particular land cover both vegetation, built-up land and others. This potential evaporation report is obtained by knowing the plant coefficient value of each land cover and reference evapotranspiration value (ETo).

The reference evapotranspiration values range from 75 to 50 mm / month. Seen on the map that the pattern of circular reference evapotranspiration regions, such a pattern occurs because the reference evapotranspiration is strongly influenced by the magnitude of the difference between the maximum and minimum air temperature values. The reference evapotranspiration on Mount Patuha has little value because when dry season the rainfall is low and has a little difference in air temperature.

The plant evapotranspiration coefficient is based on the type of vegetation that exists in the land use. Each plant has a Kc value that differs depending on the planting period and the value of the reference evapotranspiration from a particular region. Kc is the division between plant evapotranspiration and reference evapotranspiration. The higher the reference evapotranspiration, the lower the Kc value. The Kc value calculated in this study is the Kc annual average because it is an annual water yield study. This annual Kc value is obtained by averaging the initial Kc of plant growth (this Kc), the Kc of growing plants (Kc mid) and Kc of the end of the plant growth (Kc end). As shown in the table below (Table 4)

Table 4. Plant Coefficient (Kc) Various Land Uses

No.	Landuse	Kc
1	Water Bodies	0
2	Shrubs	0,65
3	Paddy Field	1,125
4	Lowland Agriculture	0,95
5	Highland Agriculture	0,92
6	Settlements	0,3
7	Tea Plantations	0,98
8	Forest	1

Source : [13]

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Potential evapotranspiration in the dry season on Mount Patuha, as seen in Fig. 5.3 shows differences in patterns with reference evapotranspiration. In the map, it appears that the difference in potential evapotranspiration values follows the shape of land use. The value of existing Kc strongly influenced PET values. The difference is seen in the land use of the built area, where the PET value drops dramatically to 15-30mm/month. This is because the value of Kc from the built area is very low compared to other land uses. Whereas in other land uses such as tea, the forest shows a similar range of PET values even though the ETo is different in air temperature.

3.3 Water Needs

Based on the classification issued by the Directorate General of Cipta Karya in 2017 [20] regarding water requirements for specific characteristics, the three districts in Mount Patuha included in the class of small cities whose population ranges from 20.000 to 100.000 inhabitants. Regions with small town classes need water for domestic needs of the population of 110 liters per day or 40.150 liters per year. The area of settlements on Patuha Mountain reaches 1.816 hectares. If the total population is divided by the area of the settlement, it is known that in one hectare there are 121 people. If calculated in m^3 per year, then the human water requirement per hectare is 4.858 m^3 per hectare per year. Furthermore, agricultural land, plantations, and forests also need water to grow the vegetation on it. Water requirements for plants are also called evapotranspiration. In this study, water requirements for plants were calculated by measuring how much actual evapotranspiration in each sub-watershed.

3.4 Water Yield

Based on the results of the analysis using the InVEST Water Yield model it can be seen that the volume of water yield for the year at Patuha Mountain is 1,202 million meters3 / year as presented in table 5. In the dry season, which is from June to September, the volume of monthly average water yield in the Patuha Mountain area is 85 million m^3. This amount is only 7 percent of the volume of annual average water yield. Many factors cause this very small number. Minimal rainfall, which is only around 70 - 100 mm/month is the main factor in decreasing water yield on Patuha Mountain. Little rainfall results in less water entering and flowing in a sub-watershed. Little water yield can be seen in the sub-watershed in the North of Patuha Mountain, where with limited rainfall, there is also less water yield compared to other sub-watersheds. If viewed spatially, the pattern of distribution of water yields on Patuha Mountain follows the annual rainfall pattern as shown in Fig. 5.4. Areas with high rainfall tend to have large water yields, and vice versa.

The highest volume of water yield per year is in the Cipandak sub-watershed of 116 million m3/year. The dominant factor that causes the Cioleh-oleh sub-watershed to have a large volume of water yield in the area of each sub-watershed. For example in the Cioleh-Oleh watershed with the Cipandak sub-watershed, where the area of the Cioleh-Oleh sub-watershed is larger, the volume of water products in the Cioleh sub-watershed is smaller than the Cipandak sub-watershed because it has smaller rainfall. But in the dry season, the water yield in this sub-watershed is only 8.6 million m3, the highest water yield in the dry season is found in the Cikahuripan sub-watershed, which is 8.9 million m3. The condition happens because the rainfall in the Cikahuripan sub-watershed is larger and the area is smaller than the Cioleh-Oleh sub-watershed.

Table 5. Annual Water Yield on Mount Patuha

No	Sub-Watersheds	Area (ha)	Water Yield Volume (M^3)
1	Cibodas	753	16.135.066
2	Cibungur	766	23.766.967
3	Cibubuay	791	18.556.554
4	Cipelah	800	24.213.806
5	Cijulang	824	25.649.288
6	Cibadak	840	26.148.295
7	Cimaragang	842	26.246.614
8	Cigenteng	882	23.851.779
9	Cipandak Kidul	1.808	57.148.795
10	Rancabali	2.114	71.720.034
11	Cisondari	2.229	60.484.342
12	Cijadi	2.264	62.787.603
13	Cipanganten	2.420	80.454.921
14	Cibuni	2.485	81.198.836
15	Cicangkorah	2.559	65.319.415
16	Ciparay	3.183	99.489.235
17	Cigodog	3.345	100.633.490
18	Cikahuripan	3.353	107.567.274
19	Cipandak	3.645	117.510.445
20	Cioleh oleh	3.651	113.339.752

Source: Personal Data Processing

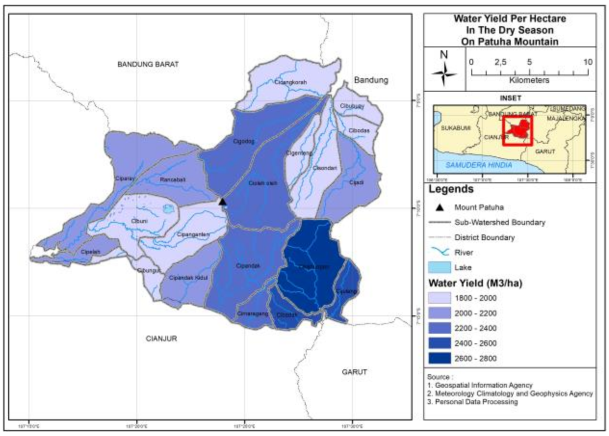

Fig 4. Water Yield Per Hectare In The Dry Season

To equalize the value of water yield in each sub-watershed with a different area, the water yield must be calculated per hectare. The yield of water per hectare is obtained by dividing the volume of water with the area of the sub-watershed area in hectares. After that, the average value of water yield per hectare per sub-watershed is obtained. The amount of water volume influences the value of water yield in a sub-watershed with the area of sub-watershed itself, the greater the volume of water, the higher the value of water yield per hectare. On the other hand, the wider sub-watershed area, water yield per hectare will be lower. As seen in the Cimaragang sub-watershed and Cipandak sub-watershed, with a very different volume of water and a difference in the area of the sub-watershed of 2800 hectares, it has almost the same value of water per hectare.

Table 6. Water Yield in the Dry Season on Mount Patuha

No.	Sub-watersheds	Area (ha)	Rain Total (M^3)	AET Total (M^3)	Water Yield Volume(M^3)	Water Yield (M^3/Ha)
1	Cibodas	753	2.823.625	1.466.308	1.357.318	1.803
2	Cibungur	766	2.974.051	1.513.946	1.460.104	1.907
3	Cibubuay	791	2.951.684	1.391.881	1.559.803	1.973
4	Cipelah	800	3.179.659	1.461.561	1.718.098	2.149
5	Cijulang	824	3.580.049	1.454.267	2.125.782	2.581
6	Cibadak	840	3.615.226	1.549.589	2.065.638	2.458
7	Cimaragang	842	3.532.063	1.644.992	1.887.072	2.242
8	Cigenteng	882	3.239.340	1.553.354	1.685.986	1.911
9	Cipandak Kidul	1.808	7.246.803	3.575.822	3.670.981	2.030
10	Rancabali	2.114	8.500.633	4.101.148	4.399.485	2.081
11	Cisondari	2.229	8.581.689	4.337.048	4.244.641	1.904
12	Cijadi	2.264	9.119.982	4.473.931	4.646.051	2.052
13	Cipanganten	2.420	9.592.756	4.786.922	4.805.834	1.986
14	Cibuni	2.485	9.549.515	4.800.090	4.749.425	1.911
15	Cicangkorah	2.559	9.617.963	4.527.876	5.090.088	1.989
16	Ciparay	3.183	12.619.907	6.096.456	6.523.451	2.050
17	Cigodog	3.345	13.526.717	5.868.090	7.658.628	2.290
18	Cikahuripan	3.353	15.431.906	6.492.431	8.939.475	2.666
19	Cipandak	3.645	15.420.985	7.097.729	8.323.256	2.283
20	Cioleh oleh	3.651	15.019.254	6.353.331	8.665.923	2.374

Source: Personal Data Processing

Table 7. Water Supply in the Dry Season on Patuha Mountain

No	Sub-Watersheds	WY/ha (M^3/Ha)	WC/ha (M^3/Ha)	WS/ha (M^3/Ha)
1	Cibodas	1.803	40	1.762
2	Cibungur	1.907	0	1.907
3	Cibubuay	1.973	47	1.926
4	Cipelah	2.149	0	2.149
5	Cijulang	2.581	0	2.581
6	Cibadak	2.458	0	2.458
7	Cimaragang	2.242	0	2.242
8	Cigenteng	1.911	197	1.713
9	Cipandak Kidul	2.030	0	2.030
10	Rancabali	2.081	44	2.037
11	Cisondari	1.904	64	1.841
12	Cijadi	2.052	2	2.051
13	Cipanganten	1.986	0	1.986
14	Cibuni	1.911	9	1.902
15	Cicangkorah	1.989	76	1.913
16	Ciparay	2.050	20	2.029
17	Cigodog	2.290	286	2.004
18	Cikahuripan	2.666	0	2.666
19	Cipandak	2.283	0	2.283
20	Cioleh oleh	2.374	335	2.039

Source: Personal Data Processing

Water supply per hectare (WS/ha) on Mount Patuha in the dry season as shown in table 7, ranges from 1700 to 2.700 m^3/hectare. The highest WS/ha is owned by the Cikahuripan sub-watershed, which is 2.666 m^3/hectare, followed by the Cijulang watershed sub-sub-district which is equal to (2.581 m^3/hectare). For example, in the Cioleh-oleh by and Cipandak sub-watersheds, with the availability of water per hectare and almost the same sub-watershed area, the value of water availability per hectare between them is quite far, almost 100 m^3/hectare. Physical factors differentiate the value of water availability in the two sub-watersheds. This physical factor is in the form of land use, where in the Cipandak sub-watershed it is dominated by plantations and forests, while in the Cioleh-oleh sub-watershed, most of the land is used for agriculture and settlement. This results in very different differences in water consumption per hectare. It can be concluded that the availability of water per hectare is strongly influenced by the amount of water consumption per hectare.

Sub-watersheds with low water availability are concentrated in the northern area of Patuha Mountain, this is due to low rainfall in the region and high water consumption because it is the center of human activities and agricultural activities. Whereas the area with high water availability is found in Patuha Mountain in the west and south, because of the high rainfall and there are only a few settlements and land use is still in the form of forests and tea plantations. However, if seen from the average water availability per year, the Patuha Mountain area still has a very large water surplus, reaching 1,193 million m^3/year.

Table 8. Annual Water Supply in Mount Patuha

No.	Sub-Watersheds	WY (M^3)	WC (M^3)	WS (M^3)
1	Cibodas	16.135.066	90.944	16.044.122
2	Cibungur	23.766.967	0	23.766.967
3	Cibubuay	18.556.554	110.324	18.446.230
4	Cipelah	24.213.806	0	24.213.806
5	Cijulang	25.649.288	0	25.649.288
6	Cibadak	26.148.295	0	26.148.295
7	Cimaragang	26.246.614	0	26.246.614
8	Cigenteng	23.851.779	522.672	23.329.106
9	Cipandak Kidul	57.148.795	0	57.148.795
10	Rancabali	71.720.034	279.630	71.440.405
11	Cisondari	60.484.342	426.347	60.057.995
12	Cijadi	62.787.603	10.736	62.776.866
13	Cipanganten	80.454.921	0	80.454.921
14	Cibuni	81.198.836	69.431	81.129.405
15	Cicangkorah	65.319.415	585.612	64.733.803
16	Ciparay	99.489.235	191.759	99.297.476
17	Cigodog	100.633.490	2.870.063	97.763.427
18	Cikahuripan	107.567.274	0	107.567.274
19	Cipandak	117.510.445	0	117.510.445
20	Cioleh oleh	113.339.752	3.665.745	109.674.007

Source: Personal Data Processing

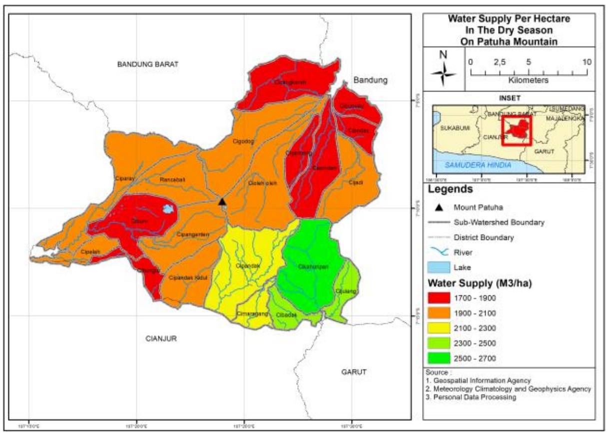

Fig 5. Water Supply Per Hectare In The Dry Season

4 Conclusion

Water yield in Patuha Mountain is divided into 20 sub-watersheds that differ in the area and physical characteristics in them. Sub-watersheds with a high volume of water products are found in the southeast part of Patuha Mountain, which is a mountainous region with an elevation of more than 1.500 masl and rainfall averaging 2.500 to 3.300 mm per year. The water yield per hectare also shows the same pattern of the volume of water products, which follows the shape of the rainfall area. In terms of water consumption, the highest volume of water consumption is owned by sub-watersheds that have land use in the form of settlements, namely sub-watersheds located in the northern part of Patuha Mountain. Water yield and water consumption will determine the availability of available water. Water availability in each sub-watershed on Mount Patuha still shows a positive or surplus value. The condition s reasonable considering the existence of Patuha Mountain as a water tower (Water Tower) which must supply water needs not only for the people who speak it but also for people in the lowland area.

Rapid population growth from year to year, especially in Indonesia, followed by an increase in the need for water. This increase in water needs must be anticipated by ensuring that the amount of water available is sufficient. For that, a model or application is needed that can calculate the availability of water in an area accurately and easily. The InVEST "Hydropower Water Yield" model is present as a conservation management tool that can help determine water availability and water requirements in an area. In the era of industrial revolution 4.0 as it is now, the InVEST model is able to determine the adequacy of water in many countries and cities in the world [15, 21]. We can find out the availability of water in an area without having to visit the region and this application can also be a reference for the government to implement policies in the field of the environment, especially the availability of water. This model is easy to use, fast in processing water availability calculations and has data sources available on the Internet. This makes the InVEST model a reliable model in the era of industrial revolution 4.0 as it is now.

However, in Indonesia, there are still some data needed by InVEST that are not available on the internet, such as rainfall data in remote areas, water requirements for humans and plants and sub-watershed boundary data. Therefore, this is a challenge for the government to be able to provide data online and integrated in order to facilitate solving environmental management problems. Through online data portals, people can easily monitor the condition of the surrounding environment and conduct research related to environmental conservation.

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