



ESTIMATION OF THE WATER BALANCE FOR A SMALL TROPICAL ANDEAN CATCHMENT

ESTIMACIÓN DEL BALANCE HÍDRICO DE UNA CUENCA ANDINA TROPICAL

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Resumen

El presente estudio estima el balance hídrico para una cuenca tropical en los Andes de Ecuador. Se estudió la variación temporal de la precipitación y la temperatura de la microcuenca Chaquilcay, ecosistema natural situado dentro del Bosque y Vegetación Protector Aguarongo en Gualaceo, Ecuador. Para examinar la variabilidad temporal de la temperatura y la precipitación, se estudiaron cuatro estaciones meteorológicas del Instituto Nacional de Meteorología e Hidrología (INAMHI) durante el periodo 1982 a 2015. Para cuantificar las contribuciones y pérdidas de agua, se llevaron a cabo análisis estadísticos de las series temporales. Mientras que, para llenar y validar las series de precipitación y temperatura, se utilizó un análisis de doble masa desarrollando estaciones de referencia y con ello completar los registros faltantes. Los datos de temperatura se complementaron con la trama isotérmica del Ecuador. Además, se usó un modelo de elevación digital (MED) para predecir la cantidad de luz solar y se aplicó el método de Thornthwaite (1948) para estimar series temporales de evapotranspiración. El análisis de balance hídrico indica 843,7 mm de precipitación anual total, una diferencia de almacenamiento de 18,71 mm que representa el 2,22 % de la precipitación anual total, un excedente de 144,5 mm y una evapotranspiración real de 680,5 mm, que asciende a 17,13 % y 80,65 % del total anual de precipitación, respectivamente.

Palabras clave: Balance hídrico, evapotranspiración, Thornthwaite, norte de los Andes, hidrología tropical.

Abstract

The present study seeks to estimate the water balance for a tropical catchment in the Andes of Ecuador. Temporal variation in precipitation and temperature of the Chaquilcay microcatchment were studied; it is a natural ecosystem situated in the Aguarongo Protected Forest in Gualaceo, Ecuador. Four meteorological stations of the National Institute of Meteorology and Hydrology (INAMHI - Instituto Nacional de Meteorología e Hidrología) were studied for 33

years (1982-2015), in order to quantify the contributions and losses of water, and statistical analyzes of the time series. To fill and validate the series of precipitation and temperature, a double mass analysis was used to develop reference stations and fill missing records. Temperature data were supplemented with the isothermal raster of Ecuador. A digital elevation model (DEM) was used to predict the amount of sun light, and the Thornthwaite method (1948) was applied to estimate time series of evapotranspiration. Our water balance analysis indicates 843,7 mm of total annual precipitation, a storage difference of 18,71 mm representing 2,22% of the total annual precipitation, surplus of 144,5 mm, and current evapotranspiration of 680,5 mm, amounting to 17,13 % and 80,65 % of the total annual precipitation, respectively.

Keywords: Catchment water balance, evapotranspiration, Thornthwaite, northern Andes, tropical hydrology.

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1 Introduction

Global changes involving simultaneous and rapid shifts in both Earth surface temperatures and land cover have resulted in profound changes to the global water balance, carbon cycle and Earth's ecosystems (Aber et al., 2001). High mountain ecosystems are particularly vulnerable to the impacts of these global changes, with documented shifts in species distribution, community composition and growth vegetation rates (Dirnböck et al., 2003; Kulonen et al., 2018; Zhañay, 2018). These changes will undoubtedly alter the catchment water balance through differential water and carbon uptake by plants as they shift in distribution and water use efficiency. A recent meta-analysis of sites worldwide of plant water use shows the importance of plant water uptake and evapotranspiration (Schlesinger and Jasechko, 2014), but the representation of tropical ecosystems in these world wide datasets is limited by lack of long-term data and study. To improve our understanding of global changes in the water balance induced by climatic and land cover change, more information and analysis of existing records –and the development of predictive models– is needed from the world's tropical regions.

The tropical Andes is one of the most hydrologically diverse regions of the world, due to the convergence of Amazonian and equatorial Pacific climate systems, combined with exceedingly steep terrain and a high level of plant biodiversity (Crespo et al., 2011). Population growth and an intensification of land use in the tropical Andes has caused alterations to natural water cycle (Ochoa Toca-chi et al., 2016). New observations from mountainous catchments in the Andes of Ecuador are revealing the importance of precipitation variability (Celleri et al., 2007; Padrón et al., 2015) and mechanisms of runoff production (Crespo et al., 2011; Mosquera et al., 2015) on the water balance.

Climate change models and downscaled products for South America are also providing new insights into the magnitude and form of climate change for South America. The global mean surface temperature variation for the period 2016 – 2035 relative to 1986 – 2005 is similar for the four RCPs, and will be in the range 0,3°C to 0,7°C (medium confidence) (IPCC, 2014). Downscaled climate model products for South America predict changes in the magnitude and seasonality of precipitation (Vera et al., 2006; Urrutia and Vuille, 2009) with predicted chan-

ges in the water balance related to different general circulation model (GCM) forcing data (Buytaert et al., 2009). Throughout South America, climate change will impact economies linked to agriculture and natural resources (Magrin, 2015; Looz Barre-zueta, 2017).

Therefore, long-term climatological records for the Chaquilcay microcatchment were studied, located at the Aguarongo Protective Forest and Vegetation (BVPA) reserve in the Ecuadorian Andes, using a spatially explicit modeling approach to derive the monthly water balance for this site. Water is considered the most important environmental good of this ecosystem, as the study area serves as one of the important water supply sources for human settlements in the region (Minga et al., 2002; Jadán, 2015). The criteria established by the National Institute of Meteorology and Hydrology (INAMHI) of Ecuador was used, with reference to the choice of the meteorological station, in addition to adopting criteria of the World Meteorological Organization (WMO) for the selection of climatological records. The aim was to evaluate temporal variability in water balance components as a baseline study for future evaluations of the impacts of climate and land-use change in the region.

2 Materials and methods

2.1 Study Area

The study area begins in the Aguarongo Protected Forest and Vegetation (BVPA - El Bosque de Vegetación Protectora Aguarongo), a protected area declared as the main source of water supply for the communities of the Gualaceo, Sigüig, and Cuenca cantons by the Ministry of Environment (MAE) (Minga et al., 2002). There are 191 streams in this ecosystem, which related to the topography of the terrain, define four microcatchments in the Paute River. The present research is directed to the Chaquilcay microcatchment, since it is the natural system with the greatest local interest.

The microcatchment of the Chaquilcay stream is located at the geographic coordinates between the meridians 78°48'54" and 78°51'8" Longitude West of the Greenwich meridian, and the parallels 2°51'28" and 2°56'35" Latitude South, represented in UTM coordinates: 742876W – 9683894S and 738733W – 9674451S, zone 17S. This microcatchment has a drain-

nage area of 20,92 Km², of which 9,39 Km² lies within the Aguarongo Forest. According to the territorial political location, the study site is located in the

Jadán parish, which belongs to the Gualaceo canton (Figure 1).

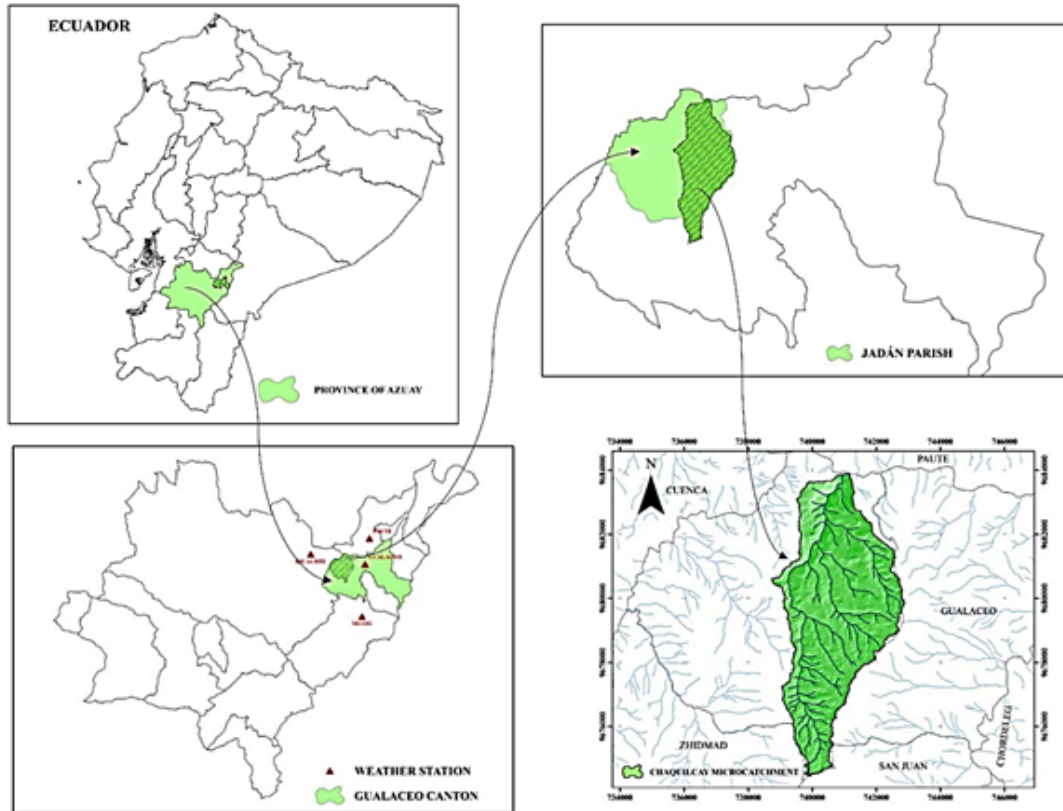


Figure 1. Location of Chaquilay microcatchment.

Among the physical characteristics of the microcatchment, it has a slope with a 34 % inclination, and lies between 3242 – 2271 masl with a difference of 971 masl between the highest and the lowest points. Concerning the edaphology, the orders of soils are Inceptisols, Mollisols, Alfisols, and the prevailing textures are clayey, loamy and loamy-clayey. Additionally, a big part of the surface is occupied by permanent crops, like cultivated grass (7.78 Km²); native forest is in the south and east of the microcatchment.

During the period 2000 – 2008 native forest was converted to shrub vegetation at a rate of 8,37Ha/year

(Minga et al., 2002; Prado Farfán, 2015). This loss of vegetation has impacted the hydrological cycle, reducing the availability of water, which due to the importance of water management and protection, generates conflicts among the settled communities. Field sampling conducted at our study site for student research indicates that soils have high levels of organic matter content and field capacities that range from 13.2 to 24.9 mm (Table 1). These highly organic soils are typical of the region and have been shown to be important for water retention and provision (Céleri and Feyen, 2009).

Table 1. Summary of statistical analysis in soil samples (Cajamarca R., 2017).

	Minimum	Maximum	Mean	Median
SOM (%)	9.2	33.8	21.3	21.29
FC (mm)	13.2	24.9	18.7	19.05

2.2 Selection of weather stations

Table 2 shows the criteria for selecting the weather stations by analyzing the station type, radius of action and terrain characteristics, in addition to considering a minimum time series length of 30 years, as proposed by the World Meteorological Organiza-

tion (WMO, 2011). Therefore, four weather stations distributed outside the Chaquilcay microcatchment were chosen. These stations recorded historical series in the period 1982-2015, acquiring monthly precipitation and temperature data from Gualaceo and Paute climatological stations, and only precipitation at the Sigsig and Ricaurte pluviometric stations.

Table 2. Summary of the selected weather stations in the analyzed period 1982-20154

Code	Station	Type of station	Distance ¹ (km)	Altitude (masl)	Measured variable ²	INAMHI radius of action ³	Missing data %
M0139	Gualaceo	Main Climatological	4.25	2230	P(mm) Mt (°C)	25 km	8.58 15.2
M0138	Paute	Ordinary Climatological	9.52	2194	P(mm) Mt (°C)	25 km	5.88 9.8
M0424	Sigsig	Pluviometric	12.57	2600	P(mm)	20 km	5.64
M0426	Ricaurte	Pluviometric	13.38	2545	P(mm)	20 km	0.98

¹ Refers to distance from weather station to catchment centroid.

² Measured variables include P = Total monthly precipitation, Mt = Mean monthly temperature.

³ Radius of action according to the recommendations of the WMO for ordinary stations.

⁴ Information obtained from the yearbooks provided by the National Institute of Meteorology and Hydrology (INAMHI).

2.3 Analysis of time series

2.3.1 Estimation of missing data

The linear regression method, which is very useful in hydrology due to its efficiency in the estimation of missing data in coastal and Andean regions of Ecuador (Carrera V. et al., 2016), was used for filling missing precipitation data. Toro et al. (2015) and Aparicio M. (2015) state that in order to estimate missing temperature data, linear regression may be applied when these conditions are met: distance < 25Km, altitude of ± 30 m, and the climate conditions at the sites are similar. Despite having an altitude of ± 36 m, this methodology was used, because the use of other methods has certain disadvantages. Within the dataset used, the adjustable arithmetic average with missing data is less than 10%.

2.3.2 Validation and homogenization of estimated values

In order to validate the estimated data, the Thom Streak Test (Barros López and Troncoso Salgado, 2010) and the double mass curve (Dingman, 2002) were performed. The first establishes a hypothesis about the median to verify the reliability of the data, and the second demonstrates by means of a graph the relationship that exists between the variables. The Thom Streak test analyzes the homogeneity or randomness of a series. This is accomplished by calculating the median value of a series and comparing individual observations to that series. Data values in the series are coded as NA values or positive when above the median ($x - Med > 0$), and as NB values or negative when below the median ($x - Med < 0$). Each sign change in the consecutive

data series is known as streak, and coded as NS. To verify homogeneity, NS values should be within the range of 10% and 90% probability for each NA. If the NS value exceeds the interval, the series is identified as random.

Double mass curve analysis is a graphical method for the evaluation of station change over the time. It is constructed as a cumulative curve of annual values of the station under study against another stations or groups of reliable stations. The series is considered stationary in time when the data plot as a straight line with a correlation coefficient r close to one. Shifts away from a 1:1 line indicate changing conditions at one station relative to the other(s). Stationarity in the double mass curve can be used to confirm the validity of the comparator station for filling missing records at a station of interest.

2.4 Estimation of missing variables

2.4.1 Temperature

Reference temperatures for stations that did not measure this variable were measured by using Extract Multi Values to Points tool of ArcGIS, using

the monthly isotherm raster of the INAMHI, for the period 1981-2010. This tool provides a means of extracting interpolated based on regional analysis of climate variables provided in these INAMHI raster.

2.4.2 Sunlight amount

To estimate hours of sunlight for evapotranspiration modeling, a DEM and an ArcGIS algorithms were used to determine the amount of solar energy through the orientation and inclination of the pixels portrayed on the elevation model. Figure 2 shows the schematic description of the preparation of data and stages that are developed to obtain amount of sunlight or hours of sunlight.

Based on the DEM, slope maps and reclassified aspects were developed and combined to obtain the morphological index (Bezzi and Vitti, 2005). This index was then processed using the ArcGIS Spatial Analyst toolbox, using FAO recommendations (Allen, 2006), to produce raster of sunlight hours using the ordinary kriging interpolation scheme. The data entered correspond to the 15th day of each month in the year 2015 with a time limit of 06:00 – 18:30.

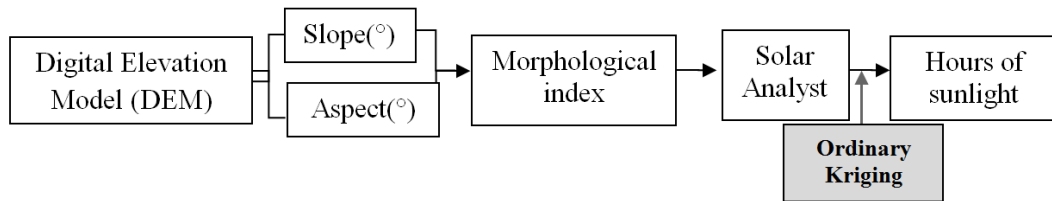


Figure 2. Hours of sunlight estimation scheme.

2.5 Estimation of the water balance

data.

2.5.1 Calculation of evapotranspiration (ET)

Due to the lack of data on the measurement of meteorological variables, the empirical method of Thornthwaite was used. This method achieves excellent results in humid climate conditions with abundant vegetation. The confidence increases even more when working with long periods between the 40°^{circ} North and 40° South parallels (Silva and Campos, 2011). For the estimation of potential evapotranspiration (ET_0), the mean monthly temperature, expressed in equations 1, 2, 3, 4 is used as input

$$ET0_c = 16 \left(\frac{10T}{I} \right)^{a(I)} Kd \quad (1)$$

Where $ET0_c$ is the corrected Potential Evapotranspiration, T is the average air temperature in the period considered [°C], I is the annual thermal index, and Kd is the coefficient of sun duration and number of days of the month. The annual thermal index (I) is defined as:

$$I = \sum_j^{12} i_j, \quad \text{with } i_j = \left(\frac{T_j}{5} \right)^{1.514} \quad (2)$$

Where T_j is the average monthly temperature. From equation (1) the exponent $a(I)$ is defined as:

$$a(I) = 6,75 \cdot 10^7 I^3 + 7,71 \cdot 10^5 I^2 + 1,79 \cdot 10^2 I + 0,49 \quad (3)$$

and the term Kd as:

$$Kd = \frac{N}{12} \frac{d}{30} \quad (4)$$

Where N is the maximum number of sun hours, depending on the month and latitude and d is the number of days in the month.

2.5.2 Spatial and temporal assessment of the water balance

To estimate the water balance, the contributions and losses of water in the Chaquilcay microcatchment were used, as described in equation 5:

$$P = ET + Q \pm \Delta S \quad (5)$$

Where P is precipitation, ET is evapotranspiration, Q is surface flow and ΔS is storage variation, with all terms measured in units of mm . The evapotranspiration term, ET , in (5) is quantified by comparison of ET_0 to P such that actual evapotranspiration (ETr) is quantified as:

$$\begin{aligned} ETr &= ET_0 \text{ when } ET_0 < P \\ ETr &= P \text{ when } ET_0 > P \end{aligned} \quad (6)$$

A soil moisture storage term ("storages") and an "excess" term were set each month, depending upon the value of $P - ET_0$, such that for months with $P - ET_0 < 0$, storage and excess were set to 0 and for $P - ET_0 > 0$, storage was set to the mean measured field capacity at our field site (18.7 mm, see Table 4) and excess was set to $P - ET_0$.

The spatial assessment of the water balance (WB) was carried out in ArcGIS, using the location of the meteorological stations with the series of precipitation and evapotranspiration. Using the Map Algebra module, the following equation (6) was generated in raster form:

$$WY = P - ET \quad (7)$$

3.1.2 Analysis of information quality

When applying the streak test to the precipitation and temperature variables, it was observed that the NS values are in the range of 10 % and 90 % for each

Where WY is the amount of water (excess or deficit in mm) and other terms are as defined above.

3 Results and discussion

3.1 Estimation of missing data

3.1.1 Application of the linear regression method

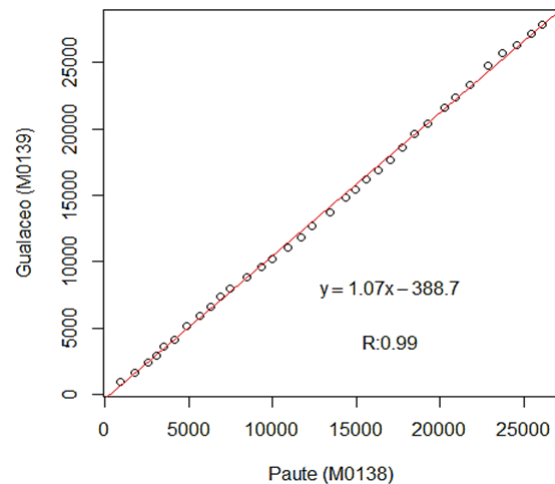


Figure 3. Double mass curve, Paute – Gualaceo stations for 33 year period of record (1982-2015).

In the study it was verified that no station presented complete data, requiring a month analysis and month correlations of the stations in order to fill the precipitation series. The findings shown in Table 6 indicate that the values of the correlation coefficient r for the meteorological stations are mostly greater than 0,5. There are small number station months with low correlation ($< 0,5$), which may be due to multiple factors in producing site to site variability in the record (for example, small scale storms recorded at one station and not in another). In spite of this, this method is widely used in some regions of South America, because there are no meteorological stations close to the station of interest (Allen, 2006; OMM, 2011).

NA. Barros López and Troncoso Salgado (2010) state that the series is stabilized in this interval, meaning that the series is homogeneous and suitable for the analysis in this study. The streak test was carried

Table 3. Streak test on annual precipitation time series.

Station	NA	NS	Homogeneity
Gualaceo	17	16	YES
Paute	17	14	YES
Sigsig	17	16	YES
Ricaurte	17	20	YES

out at the Gualaceo, Paute, Sigsig and Ricaurte stations on the annual precipitation time series (Table 3) and at the Gualaceo and Paute stations for the annual temperature records (Table 4).

Figure 3 shows that there is almost no dispersion in the double mass curve between the Paute station and the Gualaceo station, i.e., the value of correlation coefficient r is close to 1. This homogeneity is the product of the high dependence between precipitation of both stations. Moreover, since the values of the correlation coefficient r are greater than 0.9, the period 1982-2015 is considered as homogeneous. Finally, once the information is validated, the missing data is filled using the equations obtained in linear regressions.

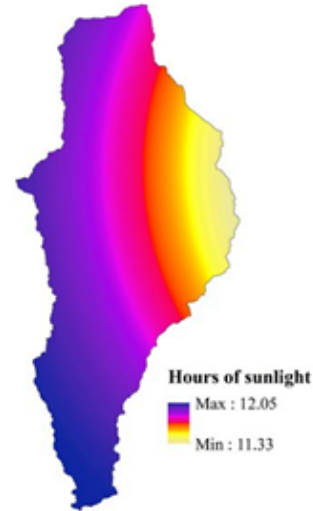


Figure 4. Estimation of hours of sunlight for the month of January.

3.2 Estimation of Reference Temperatures

The Sigsig and Ricaurte stations do not measure the temperature variable. Estimating reference temperatures of the monthly isotherms of Ecuador, it was observed that the average annual temperatures in the Sigsig and Ricaurte stations were of $14,6^{\circ}\text{C}$ and $15,5^{\circ}\text{C}$, respectively.

3.3 Estimation of sunlight amount

Figure 4 shows the minimum and maximum hours of sun for the month of January. Sunlight hours reach maximum values at the highest elevation portion of the catchment in the southwestern portion, declining to a minimum value in the lowest elevation area at the northeast extents. This analysis shows a difference of approximately one-half hour of sunlight hours in January across the catchment.

The results of Figure 5 are compared to the theoretical hours of FAO (Allen, 2006), reaching an average difference of 0,09 hours and an optimum r of 0,91, which occurred because the theoretical hours are calculated for a latitude of 2° , and due to the location of the study area, interpolations are necessary.

3.4 Calculation of water balance

3.4.1 Determination of monthly precipitation and average temperature

With the isohyets of the Chaquilcay microcatchment, monthly rainfall ranged from 24,1 to 102,5 mm, and the average annual rainfall was estimated as 843,4 mm; this precipitation decreases towards the eastern part of the catchment. Meanwhile, in the isotherms it was shown that the average annual temperature is $16,7^{\circ}\text{C}$.

Table 4. Streak test on annual temperature time series.

Station	NA	NS	Homogeneity
Gualaceo	17	14	YES
Paute	17	15	YES

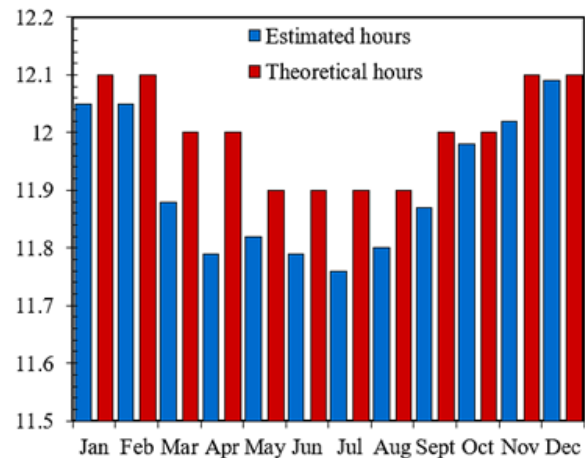
3.4.2 Calculation of Potential EvapoTranspiration (ET_0)

Monthly ET_0 ranged from 55,7 to 70,8 mm, and the annual ET_0 for the Chaquilcay microcatchment was estimated to be 748,8 mm/year. These Thornthwaite estimates agree to some extent with Contreras S. (2015), since when the meteorological information is insufficient, he recommends adjustable methods for the catchment. Del Toro Guerrero et al. (2014) also point out that the Thornthwaite technique, due to its simplicity, has the advantage of being one of the most used in the world, especially in humid areas where it provides reliable results.

3.4.3 Water balance analysis for each microcatchment

The water balance of the Chaquilcay microcatchment covers drought periods ($PP < ET_0$) in January and part of the month from June to September, receiving monthly precipitation of 24,1 to 59,1 mm, with the driest month being August. The wet season ($PP > ET_0$) is in the months from February to May and from October to December with a precipitation range of 72,5 to 102,5 mm. In addition, in the dry season, there is a water deficit, while in wettest month rainfall exceeds 18,7 mm of field capacity producing surplus water, with April being the month of greatest contribution with 41,8 mm of excess, as is shown in Table 5. This water behavior has some similarity with the results obtained by Carchi G. (2015), in the lower area of the Machángara river basin, where the months of water availability

are equivalent to the Chaquilcay microcatchment. Both places belong to the river basin of the Paute River, and above all the methodology used in the research is Thornthwaite (1948).

**Figure 5.** Comparison between estimated hours and theoretical hours of sunlight.

On the other hand, the months of highest ET_0 occur in January and December, while those with the lowest evapotranspiration go from June to September. In general, the evapotranspiration values for the microcatchment range from 55,77 mm to 70,8 mm per month. Figure 6 shows that ET_r is equal to ET_0 in the months of February to early June and from October to December. Sánchez (2010) states that optimal humidity scenarios produce this equality.

Finally, the spatial distribution of the water balance was obtained as shown in Figure 7. These maps show that there is a greater water deficit in relation to the other areas of study in the dry season, in the northern part of the microcatchment. By analyzing this distribution, it is expected that the

areas with the greatest deficit correspond to the lowest levels of the microcatchment (drainage), a place where temperature plays an important role, because it increases in the lower levels and decreases towards the higher levels. Therefore, evapotranspiration processes increase at higher temperatures.

Table 5. The monthly water balance of the Chaquilcay microcatchment [mm/month] microcatchment.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
P^1	59.1	86.8	104.8	102.5	72.5	44.9	32.7	24.1	49.3	90.1	87.2	89.7	843.7
ET_0^2	68.5	60.7	65.0	60.6	62.1	57.5	55.7	57.1	58.5	66.2	66.2	70.8	748.8
$P - ET_0^3$	-9.4	26.1	39.8	41.9	10.4	-12.6	-23	-33	-9.2	23.9	21	18.9	94.8
Storages ⁴	0	18.7	18.7	18.7	18.7	6.1	0	0	0	18.7	18.7	18.7	130.9
ETr^5	59.1	60.7	65	60.6	62.1	57.5	38.8	24.1	49.3	66.2	66.2	70.8	680.4
Excess ⁶	0	7.4	39.8	41.9	10.4	0	0	0	0	5.2	21	18.9	139.4

¹ P (average monthly precipitation)

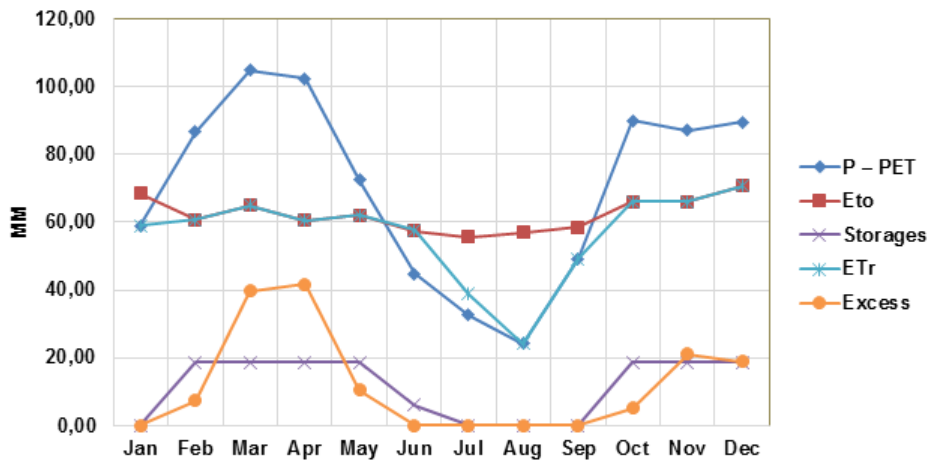
² ET_0 (potential evapotranspiration)

³ $P - ET_0$ (difference between average monthly precipitation and potential evapotranspiration)

⁴ Storages (water accumulated on the ground at the end of the month)

⁵ ETr (real evapotranspiration)

⁶ Excess (surplus of water, after meeting the needs for evapotranspiration and water in the soil to the field capacity)


Figure 6. Representation of monthly water balance in Chaquilcay microcatchment.

4 Conclusion

In the study on the Chaquilcay microcatchment, it was observed that the INAMHI information presented two major limitations. Firstly, there were few meteorological data, and secondly, the quality of information was deficient because they did not have records for the whole period 1982-2015, causing a discontinuity in the data. On applying the statistical treatments, the missing data were estimated and the approval was obtained by the streak test and high linearity by double mass curve. In total, 86 monthly data were corrected in the total of 33 years used for the studies.

Through the questions posed initially, performing a

water balance analysis made it possible to study the behavior of the hydrological processes and the effect that occurs in the water yield, thus defining the dry and wet seasons. During the dry season, water deficits occur in January, June, July, August and September, while the remaining months meet the demands of evapotranspiration, with April being the month of greatest precipitation with 102.5 mm. In addition, the annual surface runoff generated in the microcatchment was 144.5 mm, which means that there is a volume of water collected of 3.022 Hm^3 . Given the scarcity of information, the present research represents a first estimate of the water balance, providing important information for the management and planning of water resources.

Table 6. Linear regression of the relationship between precipitation stations and an associated station used as a predictor in order to fill missing records of the time series for the analyzed stations.

Month	Corrected Station ("y")	Predictor Station ("x")	Equation	r	Chaddock degree of correlation	Filled out data ¹
January	M0138	M0139	$y = 0.5721x + 12.838$	0.78	Good	1
	M0139	M0138	$y = 1.0731x + 11.935$	0.79	Good	1
February	M0138	M0139	$y = 0.5224x + 25.954$	0.59	Medium	1
	M0139	M0138	$y = 0.6704x + 32.928$	0.68	Medium	1
March	M0138	M0139	$y = 0.7373x + 25.311$	0.78	Good	1
	M0139	M0138	$y = 0.8253x + 16.803$	0.78	Good	1
April	M0138	M0139	$y = 0.3022x + 43.302$	0.43	Low	1
	M0139	M0426	$y = 0.3817x + 57.789$	0.3	Low	1
May	M0138	M0139	$y = 0.7796x + 14.038$	0.7	Good	1
	M0139	M0138	$y = 0.623x + 24.954$	0.7	Good	1
June	M0138	M0139	$y = 0.857x + 14.181$	0.75	Good	1
	M0139	M0138	$y = 0.6487x + 10.327$	0.75	Good	1
July	M0138	M0426	$y = 0.7218x + 25.394$	0.64	Medium	1
	M0139	M0426	$y = 0.5604x + 22.627$	0.44	Low	1
August	M0138	M0139	$y = 0.3045x + 24.903$	0.39	Low	3
	M0139	M0138	$y = 0.5065x + 10.637$	0.4	Low	2
	M0424	M0139	$y = 0.3275x + 40.305$	0.24	Very Low	1
	M0138	M0426	$y = 0.2303x + 24.41$	0.44	Low	3
September	M0139	M0138	$y = 0.4902x + 28.624$	0.31	Low	2
	M0424	M0138	$y = 0.4065x + 38.051$	0.28	Very Low	2
	M0138	M0139	$y = 0.6783x + 19.359$	0.63	Medium	3
October	M0139	M0138	$y = 0.5096x + 46.768$	0.6	Medium	5
	M0424	M0138	$y = 0.4072x + 20.646$	0.55	Medium	3
	M0138	M0426	$y = 0.4469x + 35.788$	0.49	Low	3
November	M0139	M0426	$y = 0.5184x + 45.556$	0.55	Medium	7
	M0424	M0426	$y = 0.2042x + 29.338$	0.37	Low	5
	M0138	M0139	$y = 0.3604x + 46.855$	0.53	Medium	5
December	M0139	M0426	$y = 0.9257x - 2.9361$	0.83	Good	12
	M0424	M0426	$y = 0.4034x + 18.5$	0.73	Good	12
	M0426	M0424	$y = 1.3278x + 20.806$	0.74	Good	4
Total						86

¹ number of monthly data that were filled in the analyzed time series.

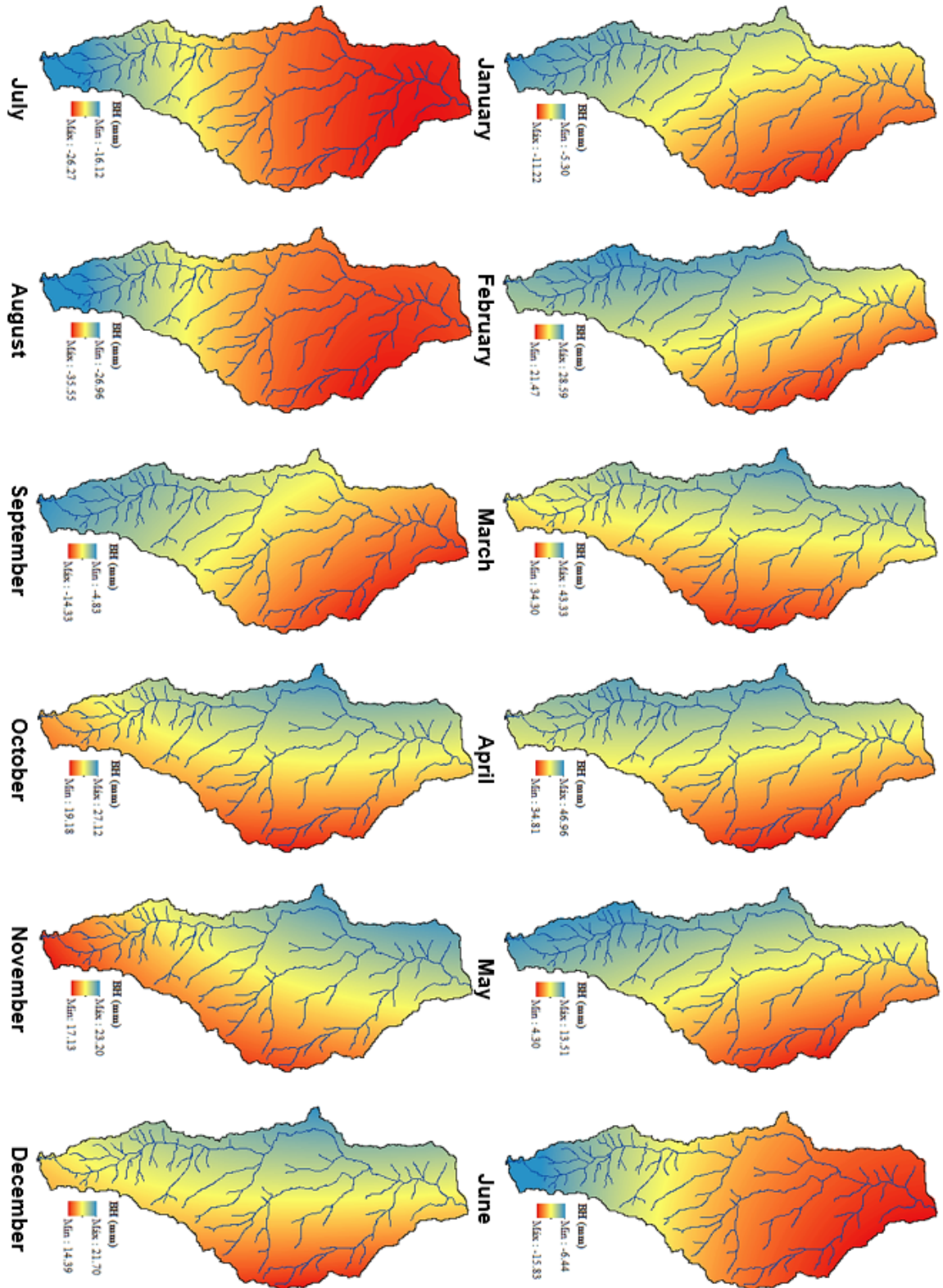


Figure 7. Spatial evaluation of the water balance (WB) obtained with ArcGIS, using the precipitation series and the monthly mean evapotranspiration values ($P - ET_0$).

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