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DETERMINATION OF POTENTIAL AND ACTUAL EVAPOTRANSPIRATION IN WATERSHED, USING MATHEMATICAL MODELS

DETERMINACIÓN DE LA EVAPOTRANSPIRACIÓN POTENCIAL Y REAL EN CUENCA HIDROGRÁFICA, UTILIZANDO MODELOS MATEMÁTICOS

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RESUMEN

En esta investigación se analiza el cálculo de la evapotranspiración real en cuencas hidrográficas, se toma como referente la quebrada Aguablanca, ubicada en el municipio de Bochalema, Norte de Santander-Colombia, donde se evalúa el balance hidrológico de esta cuenca a partir de la determinación de cálculos detallados de cuatro modelos matemáticos, para posteriormente evaluar el balance hidrológico de esta cuenca, con el fin de poder hacer una mejor administración de estos recursos, así como del uso del suelo, apostando al desarrollo de una sociedad ecológicamente sostenible y de bajo impacto ambiental. Los valores de evapotranspiración potencial y real, según el

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modelo más optimo ETP Thorwaite 874 mm/año ETR 43712 mm/año, Cenicafe 712.81 mm/año ETR 612.1 mm/año Turc ETR 884.83 mm/año cuota ETR 825 mm/año.

PALABRAS CLAVE - Evapotranspiración, Cuenca, Thorwaite, Cenicafe, Turc, Conteo.

ABSTRACT

In this research, it is analyzed the calculation of real evapotranspiration in hydrographic basins, it is taken as a reference the Aguablanca Creek, located in the municipality of Bochalema, North of Santander-Colombia, where it is evaluated the hydrologic balance of this basin from the determination of detailed calculations of four mathematical models, to later evaluate the hydrologic balance of this basin, with the purpose of being able to make a better administration of these resources, as well as the use of the soil, betting on the development of an ecologically sustainable society with low environmental impact. The values of potential and real evapotranspiration, according to the most optimal model ETP Thorwaite 874 mm/year ETR 43712 mm/year, Cenicafe 712.81 mm/year ETR 612.1 mm/year Turc ETR 884.83 mm/year quota ETR 825 mm/year.

KEYWORDS Evapotranspiration, Watershed, Thorwaite, Cenicafe, Turc, Countage.

I. INTRODUCTION

Evapotranspiration, is an important component for the correct analysis of the water balance, so that its estimation allows a correct analysis for the management of water resources, forest management, territorial planning and crop irrigation [6] [11] [13]. Evapotranspiration is a complex process within the hydrological field, since it directly influences the amount of surface and ground water. It is a term that describes the evaporation and transpiration of a plant, from the earth's surface, to the atmosphere [10] [12].

However, due to human activities, the world changes daily due to the intense acceleration of global warming, which has a direct effect on the water cycle, one of the most vulnerable aspects of an ecosystem [3]. The hydrological cycle has been affected at different times throughout history, but with the current deterioration of resources, many rivers have been on a downward trend, making the existence of water more and more difficult [1].

Climate change intensifies the circulation of the hydrological cycle in the atmosphere, which in turn alters the patterns of precipitation and evapotranspiration [5], which is one of the most difficult variables to measure in the water balance [4].

Human activities, such as the consumption of fossil fuels, and the misuse of land, have generated a great impact on ecosystems, resulting in various extreme hydrological events (floods and droughts) which, as time passes, occur more intensely and frequently [2] [8] [14].

Therefore, the change in the time of evapotranspiration must be measured in order to know the health benefits of an ecosystem, as well as the availability of water and land uses [9] but the problem lies in the lack of long-term historical series, in order to be able to perform a relevant analysis, on precipitation and temperature data and thus be able to know the value of evapotranspiration [7].

In this way, the need to study the behavior of our river basins is of supreme importance, because in this way it will be possible to estimate the amount of resources that we have and be able to establish a more adequate planning and management of these resources[15].

II. METHODOLOGY

Four different methods were used to calculate potential evapotranspiration.

2.1 Thorwaite model

This method uses the monthly temperature parameters and the average monthly hours of light, data provided by IDEAM. We find as main variables the average temperature of the month and the hours of light.

Table 1. Average monthly temperature and hours of light per month.

MONTH	AVERAGE TEMPERATURE	LIGHT HOURS
JANUARY	18.26	11,375
FEBRUARY	18.69	11,865
MARCH	19.13	12,045
APRIL	19.48	12,295
MAY	19.73	12,455
JUNE	19.57	12,325
JULY	19.42	12,505
AUGUST	19.65	12,355
SEPTEMBER	19.58	12,185
OCTOBER	19.39	11,95
NOVEMBER	19.08	11,78
DECEMBER	18.48	11,7

However, these are not the only variables. Thorwaite's potential evapotranspiration equation is:

$$ETp = 16 * \left(10 * \frac{Tm}{I}\right)^{a} \qquad (1)$$

Where:

Tm is the average monthly temperature in C

I : annual heat index

I = Summation (ij) ; j = 1, ..., 12 (which is calculated by adding the twelve monthly heat indexes).

ij = (tmj/5) 1.514

a : parameter that is calculated from I according to the expression: (2)

a = 0,000000675× I^3 - 0,0000771× I^2 + 0,01792× I + 0,49239 (3)

And finally we have to:

$$ETP_{correctec} = ETP_{thorwaite} * L \qquad (4)$$

Where:

$$L = \frac{Nº\ days\ of\ the\ month}{30} * \frac{Nº\ sunshine\ hours}{12} \qquad (5)$$

2.2 Cenicafe Model

This model allows calculating the potential evapotranspiration (PET) in a simple way, because in this equation the PET only depends on the elevation above sea level. The equation was the product of a regression elaborated by Cenicafé between the values of evapotranspiration and the height above sea level

$$ETP_{cenicafe} = 1017.17 \exp(-0.0002\ h) \qquad (6)$$

2.3 Turc Model

In the Turc model, a mass balance is established, resulting in the following expression:

$$ETR = \frac{P}{\sqrt{0.9 + \frac{P^2}{L^2}}} \qquad (7)$$

Where, ETR, is the actual evapotranspiration (mm/year), P is the average precipitation of the basin during one year (mm/year) and T is the average annual temperature in ºC.

When the P/L ratio > 0.316, equation 6 is used where L is represented by the following equation:

$$L = 300 + 25T + 0.05T^3 \qquad (8)$$

If P/L < 0.316, then ETR=P.

2.4 Countage Model

This model is based on the meteorological conditions of the basin. Where an estimation of the real evapotranspiration is made as a function of the precipitation and the temperature of the:

$$ETR = P - \lambda P^2 \quad (9)$$

Where ETR is the actual evapotranspiration in mm/year and P is the precipitation in mm/year. The lambda factor is a temperature-dependent factor.

$$\lambda = \frac{1}{0.8 + 0.14T} \quad (10)$$

T is the value of the average annual temperature in Cº. Equation 9 is only applicable for P values between $(8\lambda)^{-1}$ and $(2\lambda)^{-1}$. If rainfall is less than $(8\lambda)^{-1}$ then:

$$ETR = P \quad (11)$$

III. Results and Discussions

3.1 Thorwaite model. The results of equations 2, 3 and 5 are in the following tables:

Table 2. Result of Equation 2

MONTH	AVERAGE TEMPERATURE	I
JANUARY	18.26	7.17
FEBRUARY	18.69	7.42
MARCH	19.13	7.69
APRIL	19.48	7.90
MAY	19.73	8.05
JUNE	19.57	7.95
JULY	19.42	7.86
AUGUST	19.65	8.00
SEPTEMBER	19.58	7.96
OCTOBER	19.39	7.84
NOVEMBER	19.08	7.65
DECEMBER	18.48	7.30

The total value of I is given by the sum of all the values, therefore, I =92.80.

Thus, the value of a:

$$a = 0{,}000000675 \times 92.80^3 - 0{,}0000771 \times 92.80^2 + 0{,}01792 \times 92.80 + 0{,}49239 = 2.03$$

The values of actual evapotranspiration would be of the order:

Table 3. Potential evapotranspiration values according to the month.

MONTH	ETP
JANUARY	63.99
FEBRUARY	67.04
MARCH	70.27
APRIL	72.88
MAY	74.78
JUNE	73.56
JULY	72.45
AUGUST	74.17
SEPTEMBER	73.66
OCTOBER	72.20
NOVEMBER	69.87
DECEMBER	65.52

The factor L in equation 5 is now calculated from the data in Table 1.

Table 4. Factor L

MONTH	DAYS OF THE MONTH	HOURS OF LIGHT	L
JANUARY	31.000	11.500	0.990
FEBRUARY	28.000	12.000	0.933
MARCH	31.000	12.000	1.033
APRIL	30.000	12.500	1.042
MAY	31.000	12.500	1.076
JUNE	30.000	12.500	1.042
JULY	31.000	12.500	1.076
AUGUST	31.000	12.500	1.076
SEPTEMBER	30.000	12.000	1.000
OCTOBER	31.000	12.000	1.033
NOVEMBER	30.000	12.000	1.000
DECEMBER	31.000	11.500	0.990

Finally, the corrected evapotranspiration resulting from equation 4.

Table 5. Corrected potential evapotranspiration.

MONTH	UNCORREC-TED ETP	L	ETP CORREC-TED
JANUARY	63.99	0.990	63.37
FEBRUARY	67.04	0.933	62.57
MARCH	70.27	1.033	72.61
APRIL	72.88	1.042	75.92
MAY	74.78	1.076	80.50
JUNE	73.56	1.042	76.63
JULY	72.45	1.076	77.98
AUGUST	74.17	1.076	79.84
SEPTEMBER	73.66	1.000	73.66
OCTOBER	72.20	1.033	74.61
NOVEMBER	69.87	1.000	69.87
DECEMBER	65.52	0.990	64.88

Finally, for the calculation of actual evaporation, the Budyko equation˙

$$ETR = \{ETP * P * TAN\,(\frac{P}{ETP})\,[1 - COS\,(\frac{ETP}{P}) + SEN\,(\frac{ETP}{P})]\}^{1/2} \quad (12)$$

Where with a total potential evapotranspiration value of 872.43 mm/year and an average precipitation of 1327.6 mm/year, data provided by IDEAM.

It gives a total result of real evapotranspiration with equation 11 of 712mm/year.

3.2 Cenicafe model

The value of potential evapotranspiration according to equation 6, taking into account the average height of this basin, which is 1777.44 m, shows the following result:

$$ETP_{cenicafe} = 1017.17\,EXP(-0.0002 * 1777.44) = 712.81\,mm/año$$

Using again the previous precipitation value and using equation 11, a result of real Evapotranspiration of 612.10 mm/year is obtained.

3.3 Turc Model

For this model, the parameter L is first calculated, represented by equation 8 and with the temperature value 19.3 ºC

$$L = 300 + 25 * 19.3 + 0.05 * 19.3^3 = 1141.95$$

The P/L ratio is calculated

$$\frac{P}{L} = 1327.9/1141.95 = 1.16$$

Because it is greater than 0.316, then the calculation of actual evapotranspiration according to equation 7

$$ETR = \frac{1327.9}{\sqrt{0.9 + \frac{1327.9^2}{1141.95^2}}} = 884.83\,mm/año$$

3.4. Countange model

The first step of this model is to calculate the lambda value, established in equation 10, taking the temperature value, mentioned above, as a reference:

$$\lambda = \frac{1}{0.8 + 0.14 * 19.3} = 0.285$$

The values corresponding to (8λ)-1 and (2λ)-1 equal to 0.438 and 1.754 expressed in meters, and the precipitation is equal to 1327.9 mm or 1,327 m, therefore, it is in the range.

Actual evapotranspiration is calculated as defined by equation 10.

$$ETR = 1.327 - 0.285 * 1.327^2 = 0.825$$

IV. CONCLUSION

The calculation of the real evapotranspiration is one of the most important parameters to establish the water balance of a basin, in this case of study, the basin of the Aguablanca stream located in the municipality of Bochalema, Norte de Santander, Colombia.

The values of potential and actual evapotranspiration, according to the model are.

Table 6 . Results.

MODEL	ETP (mm/año)	ETR (mm/año)
Thorwaite	874.43	712
Cenicafe	712.81	612.1
Turc		884.83
Countange		825

To be able to carry out a water balance calculation for this river basin would have an impact on the society within this zone, because it would allow a better administration of the resources, allowing this community to develop as a low impact society.

In this case, due to the differences between evapotranspirations, one of the recommendations would be to use the highest value of real evapotranspiration for water supply calculations with respect to human use and crops in order to have a safety factor. Similarly, when designing structures that are directly related to the riverbed in this basin, use the lowest value of evapotranspiration.

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