DETERMINATION OF EVAPOTRANSPIRATION BASING ON SOLAR RADIATION IN HOA BINH PROVINCE

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SUMMARY
In the management, planning of agro-forestry and water resources, the determination of evapotranspiration is extremely important, evapotranspiration (ET) is a parameter that needs to be determined in many practical applications. The content of the article presents 4 methods to determine the amount of evapotranspiration: Turn (1961), McGuinness and Bordne (1972), Makkink (1957), Doorenbos and Pruitt (1977). All methods use meteorological data directly measured at hydro-meteorological stations in Hoa Binh province to calculate the value of solar radiation energy to estimate the average daily evapotranspiration. The results of evapotranspiration calculation by the methods are compared and the accuracy is evaluated based on direct measurement data at hydro-meteorological stations in the province. Applying the formula to calculate ET according to the following methods: Turn (1961), McGuinness and Bordne (1972), Makkink (1957), Doorenbos and Pruitt (1977), obtained ET values of 6.2 mm, 6.3 mm, 8.1 mm, 9.3 mm, respectively. Mean square error of evapotranspiration at meteorological stations calculated by the methods of Turn (1961), McGuinness and Bordne (1972), Makkink (1957), Doorenbos and Pruitt (1977), compared with the average evapotranspiration at meteorological stations measured directly is 2.1 mm, 1.9 mm, 1.3 mm, 1.9 mm respectively. The study shows that Makkink (1957) method with coefficients a = 0.9, b = 0 is suitable for calculating evapotranspiration at Hoa Binh area.
Keywords: Evapotranspiration, Hoa Binh province, meteorological data, solar radiation.

1. INTRODUCTION

Recent studies have predicted that the direct impact of climate change on water resources is mainly evapotranspiration. Hydrological change is one of the most important potential impacts on global climate change in the tropical areas (Policymakers, S.f. et al., 2007). It is clear that climate change will increase temperature and changes in precipitation. High temperatures will cause high evaporation, affecting hydrological systems and water resources. Therefore, accurate quantification of the ET value is very important and necessary for the long-term management of water resources, as well as for the design and operation of irrigation facilities specifically for the land where there are many trees in the current climate change conditions.

Evaporation is the process by which water changes from a liquid to a vapor or gaseous state. Evaporation is the return of water into the atmosphere through the diffusion of water molecules from soil, vegetation, water bodies, and other wet surfaces. Evaporation is the first step in the water cycle that water is changed from the liquid into the vapor in the atmosphere (Burnash, R., 1995). Other factors that affect evaporation are solar radiant energy, air humidity, temperature and wind velocity.

Transpiration is a phenomenon in which water vapor is released into the air from the surface of leaves and stems as a physiological response of the plant to combat the dryness around it. The total amount of water lost through diffusion of water molecules into the atmosphere is often referred to as transpiration.

ET is a term used to describe the total amount of plant evaporation and transpiration from the earth's surface to the atmosphere over a long period of time to clarify the relationship with annual precipitation (Kosugi, Y. & Katsuyama, M., 2007). This is an important variable in hydrological research. ET is used for agricultural planning, urban planning, and irrigation scheduling for crop growth patterns, regional water balance study, agro-climatic zoning, and design and operation irrigation systems (Burnash, R., 1995; Landeras, G. et al., 2008; Gocic, M. & Trajkovic, S., 2010). Direct measurements of ET around the world are rare, therefore, there is a lack of actual observational data to provide a qualitative improvement opportunity for various hydrological methods, since direct measurements of ET are costly and usually performed by high micro-quantum techniques. For many years, scientists around the world have tried to find many experimental

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methods to calculate ET values for different types of climate zones. These methods estimate ET by mathematical formula based on research and experimental results (France, J. & Thornley, J.H., 1984). The typical methods are Penman method (Penman, H.L., 1948); Jensen-Haise method (Jensen, M.E. et al., 1990); Blaney-Criddle method (Blaney, H.F., 1952); Hargreaves-Samani method (Hargreaves, G.H. & Samani, Z.A., 1985); Thorn-Thwaite method (Thornthwaite, C.W., 1948) and Van Bavel method (Bavel, C., 1966). Each method has its own advantages and is applicable to each specific climate zone. Some methods are essentially modified versions of others. The main concern in ET estimation is the reliability and accuracy of the methods. Many methods have been developed from a certain point of view for a particular climate area, so it often fails to estimate the amount of evapotranspiration that might occur under other climatic conditions. This is also a challenging problem in forecasting the ET value. Hoa Binh province in the Northwest region has a typical terrain and climate, with a warmer climate in general, the average number of sunshine hours per month is usually higher than that of other regions, the temperature difference is higher than 2-3 degrees Celsius. With strongly dissected terrain, many climate sub-regions. For these reasons, it is necessary to choose a method to determine the amount of evapotranspiration that is suitable for the climatic conditions of Hoa Binh area.

2. RESEARCH METHODOLOGY

2.1. Research location

Hoa Binh province is located at the gateway to the Northwest region of Vietnam, to the East and Northeast adjacent to the capital Hanoi, has an important position in the transition region from the plain to the mountainous area. The province is located at the gateway for exchange between the Northern Delta, the North Central Coast and the Northwest; The gateway to Upper Laos (the nearest point is 30 km from the Vietnam - Laos border), located within the range of 20°19' - 21°08' north latitude and 104°48' - 105°40' east longitude. The total area of the provincial administrative unit is 459,030 km^2 (Office, H.B.s., 2019). Hoa Binh is a mountainous province with limestone mountains running along the Southeast, parallel to the Truong Son range in the West creating many basins and valleys with rich flora and fauna systems. The mountainous terrain is complex, with steep slopes and in the direction of Northwest - Southeast, divided into 2 regions: the high mountain area is located to the Northwest with an average altitude of 600 - 700 m. In which, the terrain is difficult with an area of 212,740 ha, accounting for 44.8% of the whole area; The low mountainous area is located in the Southeast with an area of 262,202 ha, accounting for 55.2% of the province's area, the terrain consists of low mountain ranges, less fragmented, the average slope is from 20-25 degrees, the average altitude from 100 to 200 m. The river system in the province is relatively evenly distributed with large rivers such as Da River, Boi River, Buoi River, Bui River...

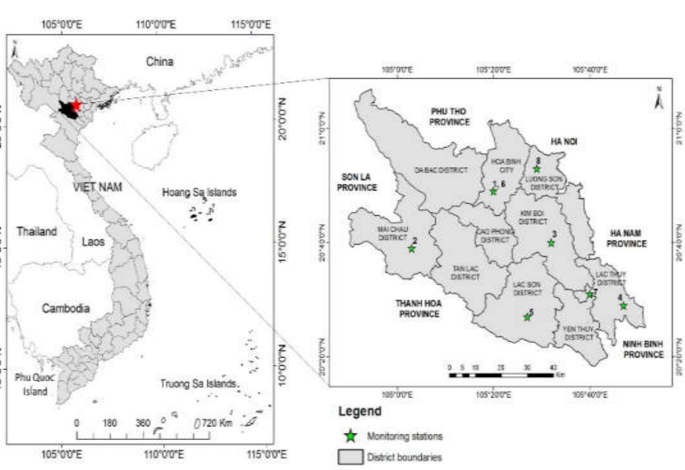

Figure 1. Geographical location of Hoa Binh province and monitoring stations

Hoa Binh has a tropical monsoon climate. The average annual temperature is 23^0C. July has the highest temperature of the year, averaging 27 - 29^0C, whereas January has the lowest temperature, averaging 15.5 - 16.5^0C. The province has an average rainfall of 1,800 mm/year; relative humidity 85%; average annual evaporation 704 mm. Due to the complex topography, the province also has the Northwest climate in the high mountains and the Northern Delta in the low mountainous area. Hoa Binh climate is divided into 2 distinct seasons: rainy season and dry season. Rainy season (hot and humid, with a lot of rain): Usually from May to the end of October, the average rainfall in many years in the rainy season reaches 1,700 - 2,500 mm, accounting for over 90% of the total annual rainfall, especially in the high mountains. Mai Chau and the lowland rainy season usually comes 15-20 days late. In particular, the three areas, Kim Boi, Chi Ne and Yen Thuy, have a larger total seasonal rainfall as well as a larger total annual rainfall, whereas Mai Chau area has the smallest total annual and seasonal rainfall. Dry season (cold, dry): Usually starts from November of the previous year to April of the following year, with the average annual rainfall of 150 - 250 mm, accounting for about 10% of the total year, especially in the months In the main winter months (December, January, February), the total monthly rainfall in most places is approximately 30 mm.

2.2. Meteorological data

Meteorological data for the calculation of evapotranspiration from various methods were collected from Hoa Binh hydro-meteorological stations on 4th June 2017 provided by the Center for Hydro-Meteorology of Hoa Binh province (Figure 2).

No.	Station	Coordinates			Strongest wind (m/s)		Average humidity (%)	Sunshine duration (hours)	Temperature (°C)		Actual water evaporation (mm)
		Longitude	Latitude	Altitude (m)	Direction	Wind speed			T (max)	T (min)	
1	Hoa Binh Meteorology	105.20	20.49	22.7	Southwest	5	50	12.1	41.0	31.0	9.6
2	Mai Chau Meteorology	105.03	20.39	165.5	Northwest	8	65	10.0	40.0	25.3	5.7
3	Kim Boi Meteorology	105.32	20.40	61.1	Northwest	4	64	10.6	40.9	27.5	7.0
4	Chi Ne Meteorology	105.47	20.29	11.3	Northwest	6	71	11.6	40.3	29.6	7.8
5	Lac Son Meteorology	105.27	20.27	41.2	Northwest	4	69	9.3	40.1	27.2	4.6
6	Hoa Binh Hydrological	105.20	20.49	22.6	Southwest	6	52	12.0	40.8	30.7	9.5
7	Hung Thi Hydrological	105.40	20.31	20.1	Northwest	5	70	11.4	40.5	30.0	8.0
8	Lam Son Hydrological	105.29	20.53	25.4	Southwest	7	67	12.3	40.9	30.5	9.2

Figure 2. Meteorological data in Hoa Binh province on 04/06/2017

(Source: Hoa Binh Provincial Hydrometeorological Station)

2.3. Evapotranspiration calculation methods

2.3.1. Turn method (1961)

Turn (1961) gives a formula for calculating evapotranspiration ET for a period of 10 days of the following form:

$$ET = 0.013\frac{T}{T+15}(R_s + 50)\ for\ RH \geq 50 \quad (1)$$

$$T = 0.013\frac{T}{T+15}(R_s + 50)(1 + \frac{50 - RH}{70})\ for\ RH < 50$$

In which:

T - Air temperature (°C);

Rs - Total solar radiation energy (Cal/cm^2/day);

RH - Relative humidity (%).

2.3.2. McGuinness and Bordne Method (1972)

McGuinness and Bordne (1972) proposed a method to calculate potential evapotranspiration based on Lysimeter measurement statistics as follows:

$$ET = \{(0.0082T - 0.19)(R_s/1500)\}2.54 \quad (2)$$

In which:

ET - Amount of evapotranspiration (cm/day);

Rs - Solar radiant energy (Cal/cm^2/day);

T - Average temperature (°F).

2.3.3. Makkink method (1957)

The Makkink method (1957) (Makkink, G., 1957) is currently widely used due to the simplification of some of the field measurement index used by the FAO 56 Penman - Monteith method. Makkink proposes the following method of calculating evapotranspiration from solar radiation:

$$ET = a\frac{\Delta}{\Delta+\gamma}\frac{Rs}{\lambda} + b \qquad (3)$$

In which:

ET - The amount of evapotranspiration (mm/day);

R_s – Solar radiation (MJ/m^2/day);

Δ - Slope of saturation vapour pressure curve (kPa/°C);

γ - Psychrometric constant (kPa/°C);

λ - Latent heat of vaporization (MJ/kg);

a, b - Linear coefficient of the Makkink method.

The linear coefficients of the Makkink method used in the calculation of evapotranspiration from determined surface at the method's proposal time (1957) were: a = 0.61 and b = 0.12. However, linear coefficients a and b depend on climatic conditions and topographical factors of each region in the world. According to Hasen's research in the Netherlands, 1984, the coefficients a, b have the values a = 0.70 and b = 0. On the other hand, a combination of Uppsala University (Sweden) and Louisiana University (USA) by Xue and Singh conducted a survey in 1999, the coefficients a and b have values of 0.77 and 0.22, respectively.

2.3.4. Doorenbos and Pruitt Method (1977)

Doorenbos and Pruitt (1977) is a radiation method that uses radiant energy to calculate evapotranspiration. This method evolved from the Makkink method (1957) introduced by Penman's method with the following formula:

$$ET = a(\frac{\Delta}{\Delta+\gamma}Rs) + b \qquad (4)$$

In which:

ET- The amount of evapotranspiration (mm/day);

Rs – Solar radiation (MJ/m^2/day);

Δ - The saturation vapor pressure curve (kPa/°C);

γ - Psychrometric constant (kPa/°C);

b = 0.3 (mm/day);

a is the correction factor between relative humidity and wind speed during the day. The coefficient a is calculated as:

$$a = 1.066 - 0.13\times10^{2}RH + 0.045U_d - 0.20\times10^{-3}RH\times U_d$$
$$-0.315\times10^{-4}RH^2 - 0.11\times10^{-2}U_d^2$$

In which:

RH - Average relative humidity (%);

Ud - Average wind speed during the day.

2.3.5. Methods of assessing accuracy

Accuracy evaluation standards use the following formulas:

- The average value (M):

$$M = \frac{1}{N}\sum_{i=1}^{N}(A_i) \qquad (5)$$

- Mean square error:

$$m = \sqrt{\frac{\sum_{i=1}^{N}(A_i-B_i)^2}{N}} \qquad (6)$$

- Average difference:

$$d = \left[\frac{1}{N}\sum_{i=1}^{N}\left|\frac{A_i-B_i}{A_i}\right|\right]\times 100 \qquad (7)$$

In which:

A_i: The amount of evapotranspiration measured directly at hydro-meteorological stations at time i;

B_i: Amount of evapotranspiration calculated by different methods at time i;

N: Number of hydro-meteorological stations.

3. RESULTS AND DISCUSSION

3.1. Results of calculating evapotranspiration from the methods

3.1.1. Turn (1961) method of evapotranspiration calculating results

Using the Turn method with formula (1) to calculate the evapotranspiration value, the following table 1 shows the results:

Table 1. Actual and estimated evapotranspiration by using Turn (1961) method

No.	Station	The amount of evapotranspiration according to the Turn method (ET_T, mm/day)	Actual evapotranspiration (mm/day)	Difference from actual evapotranspiration (mm/day)	Difference (%)
1	Hoa Binh Meteorology	6.6	9.6	-3.0	31.01
2	Mai Chau Meteorology	5.8	5.7	0.1	0.98
3	Kim Boi Meteorology	6.0	7.0	-1.0	13.89
4	Chi Ne Meteorology	6.4	7.8	-1.4	17.97
5	Lac Son Meteorology	5.6	4.6	1.0	21.35
6	Hoa Binh Hydrological	6.6	9.5	-2.9	30.77
7	Hung Thi Hydrological	6.3	8.0	-1.7	20.63
8	Lam Son Hydrological	6.7	9.2	-2.5	27.47
	Mean	**6.2**	**7.7**	**-1.4**	**20.52**
Mean square error				**2.1**	

The results show that, the highest ET value calculated by the Turn method at Lam Son hydrological station is 6.7 mm, but in fact the largest amount of ET is measured at Hoa Binh meteorological station with 9.6 mm. With the smallest ET calculated by the method and direct measurement, the same results at Lac Son meteorological station are 5.6 mm and 4.6 mm, respectively. The mean square error of the difference between the actual measurement and the Turn method is 2.1 mm.

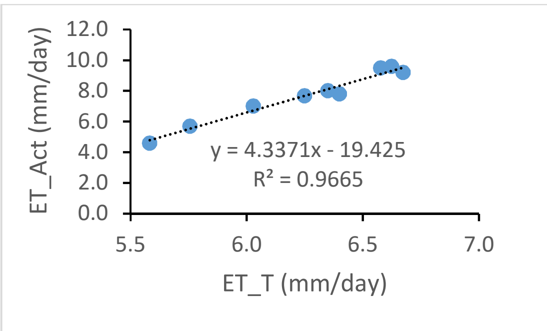

Figure 3. The correlation between actual evapotranspiration (ET_Act) and evapotranspiration calculated by Turn method *(ET_T)*

Figure 3 shows the close correlation between ET calculated by Turn method and observed data $R^2 = 0.9665$. The difference in the amount of evaporation escaping water between the data calculated by the method and the results of direct observation at meteorological stations varies from -3.0 mm to 1.0 mm, the average variation is -1.4 mm.

3.1.2. McGuinness and Bordne (1972) method of evapotranspiration calculating results

Calculation of evapotranspiration according to formula (2) - McGuinness and Bordne method results in Table 2. The results show that, the highest ET value is calculated according to the method at Hoa Binh meteorological station and Lam Son hydrology station with 6.9 mm. Meanwhile, the largest amount of ET directly measured was at Hoa Binh meteorological station with 9.6 mm. With the smallest ET calculated by the method and direct measurement, the same results at Lac Son meteorological station are 5.5 mm and 4.6 mm, respectively. The mean square error of the difference between the actual measurement and the McGuinness and Bordne method is 1.9 mm.

Table 2. Actual and estimated evapotranspiration by using McGuinness and Bordne (1972) method

No.	Station	The amount of evapotranspiration according to the McGuinness and Bordne method (ET_Mb, mm/day)	Actual evapotranspiration (mm/day)	Difference from actual evapotranspiration (mm/day)	Difference (%)
1	Hoa Binh Meteorology	6.9	9.6	-2.7	28.46
2	Mai Chau Meteorology	5.6	5.7	-0.1	1.83
3	Kim Boi Meteorology	6.0	7.0	-1.0	13.85
4	Chi Ne Meteorology	6.5	7.8	-1.3	16.55
5	Lac Son Meteorology	5.5	4.6	0.9	19.57
6	Hoa Binh Hydrological	6.8	9.5	-2.7	28.53
7	Hung Thi Hydrological	6.5	8.0	-1.5	18.92
8	Lam Son Hydrological	6.9	9.2	-2.3	25.10
	Mean	**6.3**	**7.7**	**-1.3**	**19.10**
	Mean square error			**1.9**	

The difference in the amount of the evapotranspiration between the data calculated by the method and the results of direct observation at meteorological stations varies from -2.7 mm to 0.9 mm, the average variation is -1.3 mm.

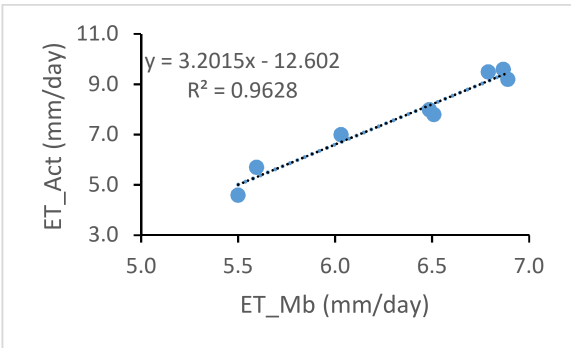

Figure 4. The correlation between actual evapotranspiration (ET_Act) and evapotranspiration calculated by McGuinness and Bordne method *(ET_Mb)*

3.1.3. The Makkink (1957) method of evapotranspiration calculating results

The Makkink method determines the amount of evapotranspiration according to formula (5) with the coefficients a, b as follows: The case ET_Mk1 has coefficients a = 0.61, b = 0.12, the ET_Mk2 case has a coefficient a = 0.9, b = 0, the ET_Mk3 case has a coefficient a = 1, b = 0, the ET_Mk4 case has a coefficient a = 0.85, b = 0 and the ET_Mk5 case has a coefficient a = 0.77, b = 0.22

In the case of a = 0.9, b = 0 (ET_Mk2), the average difference between the evapotranspiration calculated by the formula and the direct observation data is 0.4 mm, ranging from -1 mm to 2.5 mm, this is the best result in the case (Table 3). The results obtained at the Lac Son meteorological station are the lowest with the calculated evapotranspiration of 7.1 mm, the Hoa Binh and Lam Son stations are the highest with the obtained results of 8.6 mm. The mean square error m = 1.3 achieves the highest accuracy, and 0.4 mm is the difference between the calculated mean evapotranspiration data and the direct observation results at meteorological stations.

Table 3. Actual and estimated evapotranspiration by using Makkink (1957) method

No.	Station	The amount of evapotranspiration according to the Makkink method (ET_Mk, mm/day)					Actual evapotranspiration (mm/day)	Difference from actual evapotranspiration (mm/day)					Difference (%)
		ET_Mk 1	ET_Mk 2	ET_Mk 3	ET_Mk 4	ET_Mk 5		ET_Mk 1	ET_Mk 2	ET_Mk 3	ET_Mk 4	ET_Mk 5	
1	Hoa Binh Meteorology	5.9	***8.6***	9.5	8.1	7.5	9.6	-3.7	***-1.0***	-0.1	-1.5	-2.1	10.83
2	Mai Chau Meteorology	5.1	***7.4***	8.2	7.0	6.6	5.7	-0.6	***1.7***	2.5	1.3	0.9	29.83
3	Kim Boi Meteorology	5.4	***7.8***	8.6	7.3	6.9	7	-1.6	***0.8***	1.6	0.3	-0.1	10.72
4	Chi Ne Meteorology	5.7	***8.3***	9.2	7.8	7.3	7.8	-2.1	***0.5***	1.4	0.0	-0.5	5.80
5	Lac Son Meteorology	5.0	***7.1***	7.9	6.7	6.3	4.6	0.4	***2.5***	3.3	2.1	1.7	55.03
6	Hoa Binh Hydrological	5.9	***8.5***	9.4	8.0	7.5	9.5	-3.6	***-1.0***	-0.1	-1.5	-2.0	10.56
7	Hung Thi Hydrological	5.7	***8.2***	9.1	7.7	7.2	8	-2.3	***0.2***	1.1	-0.3	-0.8	2.31
8	Lam Son Hydrological	6.0	***8.6***	9.6	8.2	7.6	9.2	-3.2	***-0.6***	0.4	-1.0	-1.6	6.17
	Mean	**5.6**	***8.1***	**8.9**	**7.6**	**7.1**	**7.7**	**-2.1**	***0.4***	**1.3**	**-0.1**	**-0.6**	**4.9**
Mean square error								**2.7**	***1.3***	**1.8**	**1.3**	**1.5**	

Note: ET_Mk1 case: a=0.61, b=0.12, ET_Mk2 case: a=0.9, b=0, ET_Mk3 case: a=1, b=0, ET_Mk4 case: a=0.85, b=0, ET_Mk5 case: a=0.77, b=0.22

The correlation between the actual evapotranspiration value and the Makkink evapotranspiration value in 5 cases is shown in Figure 5 the analysis results show that the case ET_Mk2 has the highest correlation with coefficient of determination $R^2 = 0.9679$.

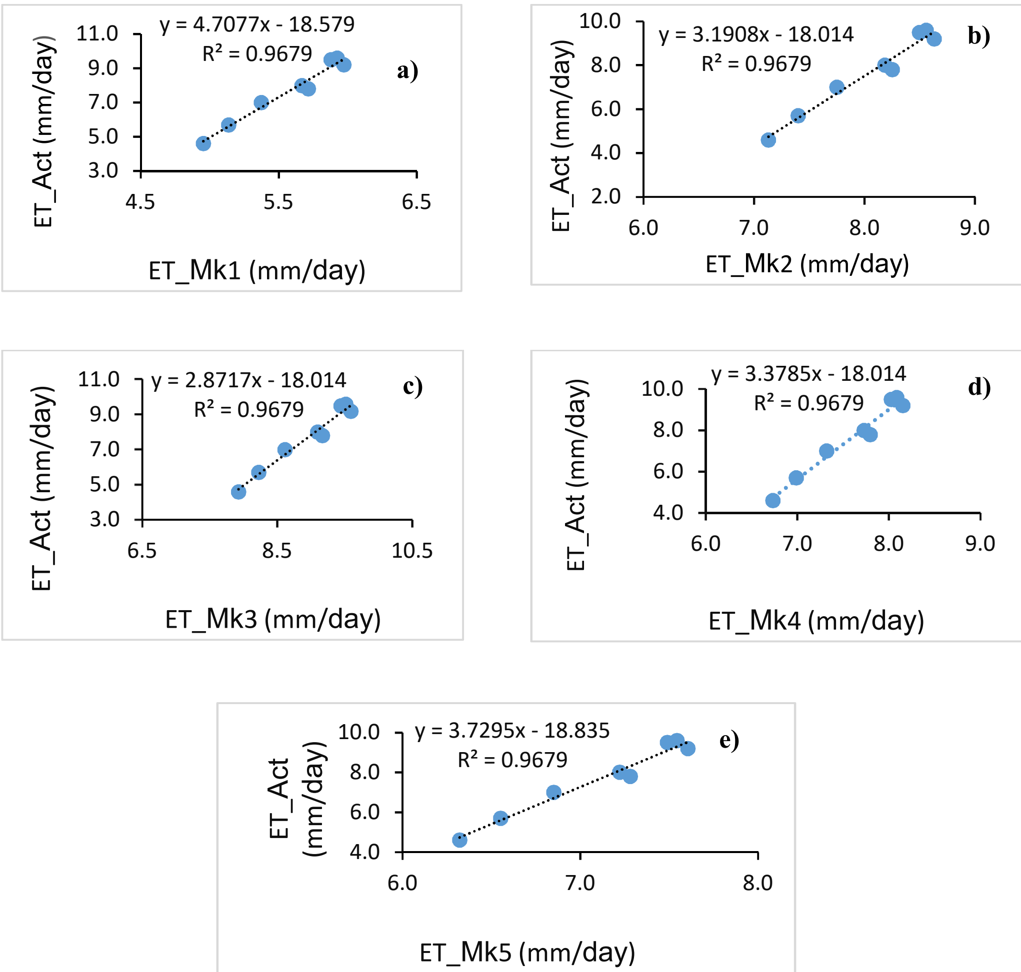

Figure 5. The correlation between actual evapotranspiration (ET_Act) and evapotranspiration calculated by Makkink method (ET_Mk)

3.1.4. Doorenbos and Pruitt (1977) method of evapotranspiration calculating results

Formula (4) is used to calculate the evapotranspiration value according to the method Doorenbos and Pruitt (1977), the calculation results are shown in Table 4. Calculation results show the difference in evapotranspiration from the data calculated by the Doorenbos and Pruitt method compared with the results of direct observations at meteorological stations, ranging from 0.7 mm to 3.1 mm and an average of 1.6 mm. The calculated value of ET according to the Doorenbos and Pruitt method (1977) at the time of June 4, 2017 shows the lowest evapotranspiration at Lac Son meteorological station with a value of 7.7 mm, the evapotranspiration is high at Hoa Binh meteorological station, Hoa Binh hydrological station with a value of 10.5 mm. The average amount of evapotranspiration at the stations is 9.3 mm. The mean square error between actual measurement results and calculated results from Doorenbos and Pruitt (1977) method is 1.9 mm.

Table 4. Actual and estimated evapotranspiration by using Doorenbos and Pruitt (1977) method

No.	Station	The amount of evapotranspiration according to Doorenbos and Pruitt method (ET_Dp, mm/day)	Actual evapotranspiration (mm/day)	Difference from actual evapotranspiration (mm/day)	Difference (%)
1	Hoa Binh Meteorology	10.5	9.6	0.9	9.07
2	Mai Chau Meteorology	8.8	5.7	3.1	54.36
3	Kim Boi Meteorology	8.6	7.0	1.6	22.95
4	Chi Ne Meteorology	9.1	7.8	1.3	16.67
5	Lac Son Meteorology	7.7	4.6	3.1	67.26
6	Hoa Binh Hydrological	10.5	9.5	1.0	10.57
7	Hung Thi Hydrological	8.9	8.0	0.9	11.49
8	Lam Son Hydrological	9.9	9.2	0.7	7.97
	Mean	9.3	9.3	1.6	20.56
	Mean square error			1.9	

Figure 6 shows that the evapotranspiration calculated by the Doorenbos and Pruitt method (1977) closely correlates with the actual evapotranspiration with $R^2 = 0.8717$. Calculation results of evapotranspiration by the method Doorenbos and Pruitt (1977) do not differ much from the results of direct observations at meteorological stations. Therefore, Doorenbos and Pruitt (1977) method can be used to calculate evapotranspiration for Hoa Binh province**.**

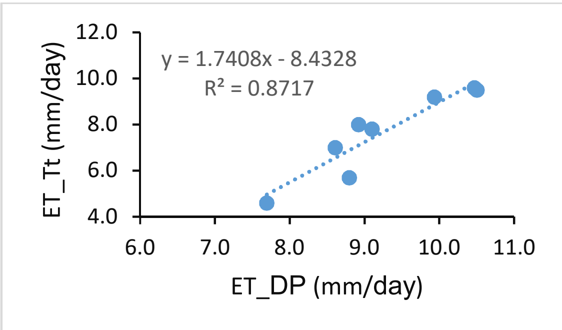

Figure 6. The correlation between actual evapotranspiration (ET_Tt) and evapotranspiration calculated by Doorenbos and Pruitt (1977) method (ET_Dp)

3.2. Compare the calculation results of evapotranspiration by different methods

Table 5. Synthesize the results of calculating the evapotranspiration value by different methods

(Unit: mm/day)

No.	Station	ET_Tt	ET_T	ET_Mb	ET_Mk2	ET_Dp
1	Hoa Binh Meteorology	9.6	6.6	6.9	8.6	10.5
2	Mai Chau Meteorology	5.7	5.8	5.6	7.4	8.8
3	Kim Boi Meteorology	7.0	6.0	6.0	7.8	8.6
4	Chi Ne Meteorology	7.8	6.4	6.5	8.3	9.1
5	Lac Son Meteorology	4.6	5.6	5.5	7.1	7.7
6	Hoa Binh Hydrological	9.5	6.6	6.8	8.5	10.5
7	Hung Thi Hydrological	8.0	6.3	6.5	8.2	8.9
8	Lam Son Hydrological	9.2	6.7	6.9	8.6	9.9
	Mean	7.7	6.2	6.3	8.1	9.3
	Mean square error		**2.1**	**1.9**	**1.3**	**1.9**

Note: ET_Tt actual amount of evapotranspiration; ET_T: Evaporation by Turn method (1961); ET_Mb: Evaporation by McGuinness and Bordne method (1972); ET_Mk2: Evaporation by Makkink method (1957) with a=0.9, b=0; ET_Dp: Evaporation by Doorenbos and Pruitt method (1977).

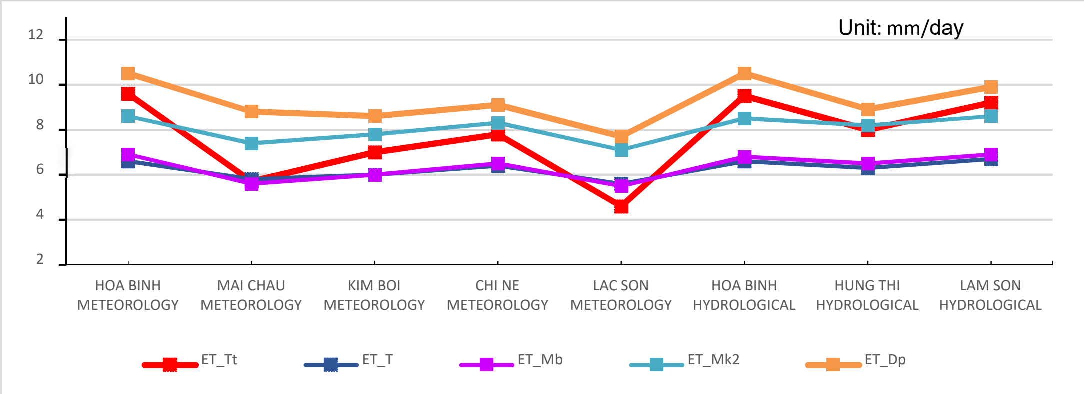

Figure 7. Comparison chart of evapotranspiration between different methods

The data show that the lowest mean evapotranspiration calculated by the Turn (1961) method is 6.2 mm, the difference from the average evapotranspiration from the direct measurement results is -1.5 mm and 2.6 mm, respectively.

The graph shows that the evapotranspiration calculated by the Makkink method (1957) with the coefficient a = 0.9, b = 0 has evapotranspiration result close to the evapotranspiration measured directly at meteorological monitoring stations.

Table 6. Pearson correlation coefficient (N = 4) analysis of mean difference between actual evapotranspiration and methods

No.	ET methods	Pearson correlation coefficient R	Mean square error: m	Average difference from reality: d (%)
1	ET_T	0.979	2.1	20.52
2	ET_Mb	0.981	1.9	19.10
3	ET_Mk2	0.984	1.3	16.35
4	ET_Dp	0.930	1.9	25.04

Based on the results in Table 6, it was found that the correlation coefficients of other methods are very good, in the range of 0.930-0.984. In which, the best correlation coefficient belongs to the Makkink method 0.984, and the smallest correlation coefficient belongs to the Doorenbos and Pruitt method is 0.930.

The method with the most accurate data compared to the actual data is the Makkink method with mean square errors of 1.3. The McGuinness and Bordne method and the Doorenbos and Pruitt method both have a mean square error of 1.9. The Makkink method is also the method with the smallest mean deviation of 16.35%. The largest difference belongs to the Doorenbos and Pruitt method with a deviation of 25.04% respectively.

4. CONCLUSION

The study determined evapotranspiration by five methods: Turn (1961), McGuinness and Bordne (1972, Makkink (1957), Doorenbos and Pruitt (1977), from meteorological data June 4, 2017.

The results show that the Makkink method has a high correlation, the lowest mean square error (R = 0.984 and m = 1.3) and the average evapotranspiration difference from the reality of 16.35% is also the smallest. Besides, the method McGuinness and Bordne (1972) also gives good correlation coefficient R = 0.981, mean square error m = 1.9 and mean evapotranspiration difference is 19.1%.

The Turn method (1961) method have a mean error greater than 2.0 and have a difference in mean evapotranspiration by more than 20%. Doorenbos and Pruitt (1977) method with mean square error m = 1.9 but correlation coefficient is 0.930 and mean evapotranspiration deviation is 25.04%.

Based on the research results, methods such as Turn (1961) and Doorenbos and Pruitt (1977) should not be used to determine evapotranspiration in Hoa Binh province.

Research shows that, it is recommended to use the Makkink method (1957) with the coefficients a = 0.9, b = 0 to determine evapotranspiration in Hoa Binh province. The research results are consistent with Hasen's study to determine the evapotranspiration in the Netherlands in 1984 by Makkink method.

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XÁC ĐỊNH LƯỢNG BỐC THOÁT HƠI NƯỚC THEO NĂNG LƯỢNG BỨC XẠ MẶT TRỜI TẠI TỈNH HÒA BÌNH

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Trường Đại học Lâm nghiệp

TÓM TẮT

Trong công tác quản lý, quy hoạch nông lâm nghiệp và tài nguyên nước, việc xác định lượng thoát hơi nước là vô cùng quan trọng, lượng thoát hơi nước (ET) là một thông số cần được xác định trong nhiều ứng dụng thực tế. Nội dung bài báo trình bày 5 phương pháp xác định lượng thoát hơi nước: Turn (1961), McGuinness and Bordne (1972), Makkink (1957), Doorenbos and Pruitt (1977), Jensen and Haise (1963). Tất cả các phương pháp đều sử dụng dữ liệu khí tượng đo trực tiếp tại các trạm khí tượng thủy văn tỉnh Hòa Bình để tính giá trị năng lượng bức xạ mặt trời nhằm ước tính lượng bốc hơi trung bình ngày. Áp dụng công thức tính ET theo các phương pháp sau: Turn (1961), McGuinness and Bordne (1972), Makkink (1957), Doorenbos and Pruitt (1977), Jensen and Haise (1963) thu được giá trị ET lần lượt là 6,2 mm; 6,3 là mm, 8,1 mm; 9,3 mm. Sai số trung phương lượng bốc thoát hơi nước tại vị trí các trạm khí tượng tính theo phương pháp Turn (1961), McGuinness và Bordne (1972), Makkink (1957), Doorenbos và Pruitt (1977), Jensen và Haise (1963) so với lượng bốc hơi trung bình tại các trạm khí tượng đo trực tiếp lần lượt là 2,1 mm, 1,9 mm, 1,3 mm, 1,9 mm, 3,0 mm. Nghiên cứu cho thấy phương pháp Makkink (1957) với hệ số a = 0,9; b = 0 là phù hợp để tính lượng bốc thoát hơi nước tại khu vực Hòa Bình.

Từ khóa: Bức xạ mặt trời, dữ liệu khí tượng, thoát hơi nước, tỉnh Hòa Bình.

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