Estimation of actual evapotranspiration and soil water content in the growing season

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Introduction

Actual evapotranspiration (ET) – sum of evaporation and plant transpiration from the Earth's land surface – is one of the main components of the hydrological cycle. ET equally depends on atmospheric, soil and plant factors, and this is the reason why it has great spatial heterogeneity. As the measurement of ET is a complex task and requires expensive methods (in contrast to the measurement of precipitation), its operational measurement-based evaluation cannot be achieved due to the lack of both technical and economic conditions. Thus, ET changes in space and time have to be evaluated by models.

Three model types are known for evaluating ET:

1. Models that evaluate ET on the basis of the potential evapotranspiration (PET) by calculating the so-called β function. This method was mainly used for estimating plant transpiration (e.g. MINTZ & WALKER, 1993), and is rarely used nowadays.

2. Models that evaluate ET as a function of both the water availability on the surface and the atmospheric demand. The estimated ET is the lower value of these two calculated ETs. In case of transpiration, root water uptake equally depends upon vegetation and soil properties (MONTEITH, 1995).

3. Models that evaluate ET by calculating the so-called surface resistance of the vegetation or bare soil surface (MONTEITH, 1965). Surface resistance greatly depends on the water availabilty of the surface as well as on the incoming solar radiation (ÁCS et al., 2005). Surface water availability is substantially determined by soil hydraulic properties. Nowadays these models are the most prevalent.

Model types 2 and 3 contain many data which are not inevitably available everywhere especially for a long term. This is the reason why model type 1 was often used (STONE et al., 1977; POSZA & STOLLÁR, 1983; SZÁSZ, 1988; MINTZ & WALKER, 1993; MOCKO & SUD, 1998). In addition to β calculation, all these methods apply "bucket models" for estimating soil moisture content (MANABE, 1969).

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In Hungary, the knowledge of ET and actual soil moisture regime has always been important because of the ongoing agricultural production. For this purpose, the method of THORNTHWAITE (1948) was adapted. Thornthwaite's method was applied by BERÉNYI (1943), SZESZTAY (1958) and KAKAS (1960). SZESZTAY (1958) considered the method from hydrological point of view and applied it to smaller catchment areas. Mention should also be made of the Carpathian Basin related work of SZEPESINÉ (1966) in which she investigated the energy balance of some stations. In these calculations the available moisture content of soil was uniformly 300 mm. SZÁSZ (1963) also used Thornthwaite's method for the analysis of the relationship between some elements of soil moisture regime and the available moisture content at some stations. In these studies the effect of spatial variability of soil hydraulic properties on evapotranspiration was not taken into account.

The present paper discusses a modified version of the Thornthwaite model in which the effect of soil on evapotranspiration is taken into consideration. Thornthwaite's original model was modified in two aspects:

1. In addition to potential evapotranspiration, actual evapotranspiration was also calculated and

2. in the calculation of the available moisture content of soil, soil texture was also taken into account.

With the first modification, the original Thornthwaite parameterization (e.g. parameterization of water surplus) was changed, which increased the applicability of the model to mesoscale. With modification 2 the effect of the spatial variability of soil texture classes on evapotranspiration was taken into account. In model applications we shall focus on: a) the verification experiments using domestic data, b) the statistical analysis of evapotranspiration–soil moisture regime–environmental factors (e.g. precipitation and/or temperature) relationships, and c) the analysis of changes in ET and soil moisture content in the space and time.

Methods and Data

The modified version of the Thornthwaite based model

In the modified Thornthwaite based model, soil water content is estimated by a bucket model, while ET is parameterized by using a β function. Input data of the model consists of climatological and soil data. Climatological data include monthly temperature and precipitation data, while soil data consist of the initial soil water content and data belonging to field capacity (VK_{sz}) and wilting point (VK_h) soil water contents for the given soil texture class. The output data are: a) actual evapotranspiration (ET), b) potential evapotranspiration (PT), c) soil water content (VK), d) water surplus (S) and e) Thornthwaite's climate formula.

In the model the depth of the soil profile and root zone is 1 m. This is obviously a rough approximation, but in this study the spatial variability of the root zone depth was not taken into consideration. ET strongly depends on the β function, for which the MINTZ & WALKER's (1993) parameterization referring to grass-covered surface is used. The model is unable to distinguish between bare (uncovered) soil surface and vegetation. It distinguishes five soil texture classes, but does not differentiate between salt-affected soils and others. The model does not simulate processes typical for the winter season, it doesn't estimate snow or ice melting, or freezing/thawing of soil water. Relief conditions and groundwater depth were not taken into account in the course of water surplus parameterization. The model gives no information on the runoff of the water surplus.

In spite of these weaknesses, the present model version is an improvement of the former Thornthwaite model, as it makes possible the mesoclimatological estimation and evaluation of the relationships between ET and soil properties.

Calculation of ET and soil water content

ET depends on the so-called β function

$$ET = \beta \cdot PET \tag{1}$$

where: β is the ratio between actual evapotranspirtaion (ET) and potential evapotranspiration (PET).

Among PET parameterizations, THORNTHWAITE's (1948) parameterization is one of the best known.

THORNTHWAITE'S (1948) parameterization. – THORNTHWAITE (1948) estimated PET on the basis of temperature and potential sunshine duration data. He formulated the PET equation in the United States using lysimeter measurement data. The equation does not include the effect of advection and the albedo constant. MCKENNEY & ROSENBERG (1993) modified this formula, as follows:

$$PET = 1{,}6 \cdot \left(\frac{L}{12}\right) \cdot \left(\frac{N}{30}\right) \cdot \left(\frac{10T}{I}\right)^{a} \tag{2}$$

where: L is the monthly mean daytime length (hours), N is the number of days in the month, T is the monthly mean temperature and I is the heat index. PET is given in [mm·month^{-1}]. I can be expressed as

$$I = \sum_{j=1}^{12} \left(\frac{T}{5}\right)^{1{,}514} \tag{3}$$

$$a = 6{,}75 \cdot 10^{-7} \cdot I^{3} - 7{,}71 \cdot 10^{-5} \cdot I^{2} + 1{,}792 \cdot 10^{-2} \cdot I + 0{,}49239 \tag{4}$$

Parameterization of β – According to MINTZ & WALKER's (1993) measurements above grass-covered surface:

$$\beta = 1 - \exp\left(-6{,}8 \cdot \frac{VK - VK_{h}}{VK_{sz} - VK_{h}}\right) \tag{5}$$

where: VK is the actual soil water content [$mm \cdot m^{-1}$], while VK_{sz} and VK_h is the soil water content [$mm \cdot m^{-1}$] denoting field capacity and wilting point, respectively. Note that the relationship between β and VK is strongly nonlinear because of the 6.8 coefficient in the exponent.

Calculation of soil water content –The following numerical expression was used for calculating soil water content:

$$VK_{t+1} = VK_t + \frac{F(VK_t)}{1 - \frac{1}{2} \cdot \left. \frac{\partial F}{\partial VK} \right|_t \cdot \Delta t} \tag{6}$$

where: F(VK) is a function which can be expressed as F(VK)= P-ET(VK)-S(VK). Δt is the time scale, in the present case it amounts to 1 month. For January, the Euler explicit scheme is always used. The final VK_t was estimated by averaging VK_{t+1} and VK_t. Irrespective of the scheme used, the initial value of VK_t is unknown. It should be mentioned that the proper choice of the initial value of VK considerably determines the length of the calculation, therefore the initial value of VK should be estimated as accurately as possible.

Data

Climatic data – Climatic data consist of monthly precipitation–temperature (hereafter briefly P–T) data of 115 meteorological stations referring to the period between 1901 and 1950 (KAKAS, 1960). It should be noted that there is only a slight disparity between these precipitation and temperature fields and the newest P and T fields presented in the Climate Atlas of Hungary (2000). The P-T diagram of the stations involved in the study is presented in Fig. 1.

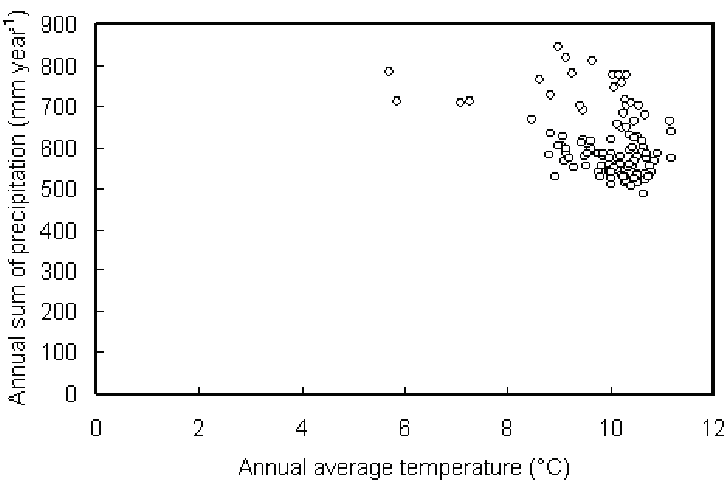


Fig. 1
Annual P-T values of 115 meteorological stations. Data refer to the 1901–1950 period

Soil data – Soil data include soil water content values referring to field capacity and wilting point. The VK_{sz} and VK_h values depend on soil texture and on the determination method. Five main soil texture categories were distinguished: sand, sandy loam, loam, clay loam and clay. Soil texture of the meteorological stations was determined according to VÁRALLYAY (1990). The values of VK_{sz} and VK_h were determined after NEMES (2003) and are presented in Table 1.

Table 1
Soil water content values at wilting point (VK_h) and at field capacity (VK_{sz}) for the main five soil texture categories

Parameter	Soil texture				
	Sand	Sandy loam	Loam	Clay loam	Clay
VK_h ($mm \cdot m^{-1}$)	15.2	104.7	135.5	175	271.9
VK_{sz} ($mm \cdot m^{-1}$)	79.9	273.8	331.7	386.9	485.4

In the work of NEMES (2003) the parameter values of VAN GENUCHTEN's (1980) pF curves are presented for the 11 USDA (United States Department of Agriculture) soil texture classes. The relationships between the USDA and the Hungarian classification are taken from the study of FILEP and FERENCZ (1999). Soil water content value at wilting point (VK_h) was calculated from the $pF(VK_h) = 4.2$, while that of field capacity (VK_{sz}) from the condition $pF(VK_{sz}) = 2.5$. It should be noted that VK_{sz} can also be estimated by using some other conditions (ÁCS, 2005). Sand, the coarsest soil texture, has the lowest VK_h and VK_{sz} values. VK_h and VK_{sz} values increase with the decrease in particle sizes. The accession rate is the most significant between sand and sandy loam.

Data of the Agrometeorological Observatory of the Debrecen University

The modified version of the Thornthwaite model was tested on long-term series of precipitation, temperature and soil water content data obtained at the Agrometeorological Observatory of the Debrecen University located in Hajdúhát (47°37'N, 21°36'E, h=112 m). Hajdúhát can be characterized by a temperate rainy climate with continental features. The annual mean temperature is 10.1 ºC, while the mean annual precipitation sum is 550 mm. The water table is at a depth of 10 m. The chernozem soil is situated on a loess ridge and has loamy texture. The vegetation is shortcut natural grass. Soil water content values for VK_{sz} and VK_h are 360 and 150 $mm \cdot m^{-1}$, respectively. Data refer to the period from 1972 to 1992. Soil water content was measured weekly, the monthly measurements varied between 4 to 6. In the winter season measurements were often suspended because of frost or snow. From the 21-year time series on soil water content the data of 4 December, 10 January and 9 February months are missing.

Samples (with a height and diameter of 10 cm) were taken from the 0–5, 5–10 cm layers on the surface, then from each 10 cm layer downward to the 1 m depth.

The samples were regularly collected from the 0–100 cm layer, but in some periods down to 150 cm depth. Soil water content values were determined by the gravimetric method. From each sample 200 g soil was dried on 105 ºC until the sample reached a constant weight. The dry weight of the sample was immediately determined after drying. The soil moisture measurement procedure was identical throughout the investigated period.

The plotting system – Figures presenting areal distributions are plotted by the *SurGe Project Manager* programme. The programme first plots a grid using stations' coordinates and the values of the variables. In the second step, it generates values by interpolation in all grid points. Lastly, it presents the obtained field. Interpolation is carried out by the so-called „ABOS" method (Approximation/ interpolation Based On Smoothing) (DRESSLER, 2003), which is a mix of kriging and „minimum curvature" methods. The accuracy of the method is similar to that of the kriging method.

Results

Verification tests

Changes in the measured and simulated VK values were analyzed in the period between 1972 and 1992. Long-term mean annual course of measured and simulated soil water content (VK) and their standard deviations are presented in Fig. 2.

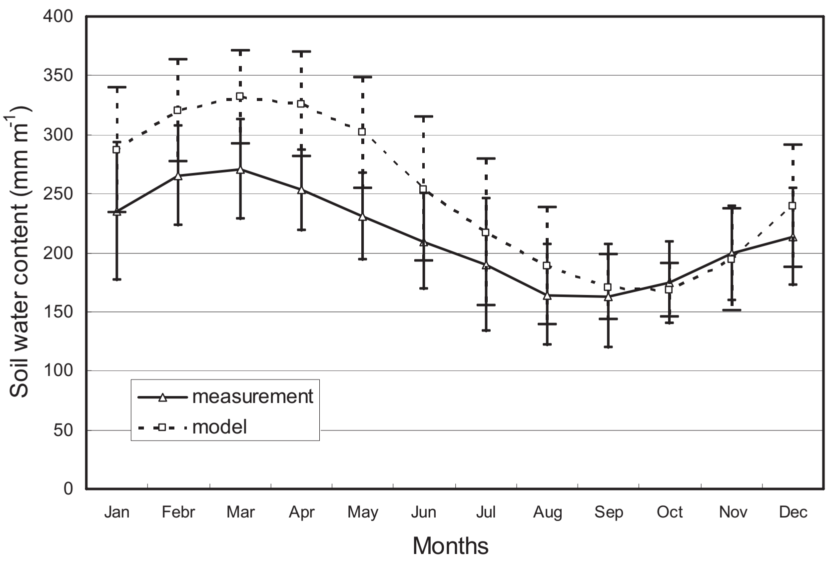


Fig. 2

Long term mean annual course of measured and simulated soil water content (VK) and their standard deviations. Courses refer to the 1972–1992 period

With the exception of February and the spring months, simulated monthly mean VK values were within the variation of the measured monthly mean VK values, that is, $VK_{mea} - \sigma_{mea} < VK_{sim} < VK_{mea} + \sigma_{mea}$. At the same time, there was no month for which $VK_{sim} - \sigma_{sim} > VK_{mea} + \sigma_{mea}$ was valid. The greatest deviations were found in April and May, when VK_{sim} was about 75 mm·m^{-1} larger than VK_{mea}; a difference amounting to 30%. The spring deviations are evidently related to the calculation and measurement of VK and S. The simulation and/or measurement of spring water surplus and changes in the water content is a complex task, as moisture distribution depends both on the characteristics of soil and relief. One of the major future tasks is the better understanding and handling of the relationship between spring soil moisture regime and runoff. It should be noted that from the viewpoint of the calculation of evapotranspiration the estimation of the spring water surplus is irrevelant, as potential evapotranspiration prevails at the time.

Deviations in January and February could be eliminated with the introduction of processes simulating snow/ice formation and melting on the soil. For this purpose application of the surface energy balance equation is required, which has not been included in the model as yet.

Statistical analyses

The relationship between output variables (ET and VK) and climatic data (P and T) is characterized by linear regressions according to the soil texture classes and

Table 2

Relationship between the main output variables (ET and VK) and the climatic data (P and T) for different soil texture classes and selected periods

Period	Sand		Sandy loam		Loam		Clay loam		Clay	
		R^2		R^2		R^2		R^2		R^2
Correlation between the evapotranspiration (ET) and the air temperature (T), precipitation (P) and soil water content (VK)										
January	–	–	–	–	–	–	–	–	–	–
February	–	–	T	0.64	–	–	–	–	–	–
March	T	0.93	T	0.81	T	0.84	T	0.95	T	0.98
April	T	0.93	T	0.90	T	0.86	T	0.97	T	0.88
May	T	0.68	P	0.94	T	0.85	T	0.99	T	0.58
June	VK	0.92	T	0.74	T	0.89	T	0.99	T	0.58
July	P	1	P	0.97	VK	0.72	VK	0.55	VK	0.97
August	P	1	P	0.98	P	0.94	VK	0.85	P	1
September	P	1	P	0.99	P	0.99	P	0.92	P	1
October	T	0.93	T	0.79	T	0.82	T	0.96	T	0.96
November	T	0.94	T	0.77	T	0.85	T	0.94	T	0.99
December	T	0.79	T	0.94	T	0.88	–	–	T	0.99
Year	P	0.93	P	0.90	P	0.88	–	–	P	0.98

Table 2 continued

Time	Sand		Sandy loam		Loam		Clay loam		Clay	
		R^2		R^2		R^2		R^2		R^2
Correlation between the soil water content (VK) and the air temperature (T), precipitation (P) and evaporation (ET)										
January	–	–	P	0.68	P	0.66	P	0.79	T	0.61
February	–	–	–	–	–	–	P	0.53	–	–
March	–	–	–	–	–	–	–	–	–	–
April	P	0.75	P	0.64	P	0.52	P	0.51	–	–
May	P	0.86	P	0.88	P	0.77	P	0.92	–	–
June	ET	0.92	P	0.84	P	0.46	T	0.81	P	0.76
July	–	–	ET	0.85	P	0.74	T	0.9	ET	0.97
August	–	–	ET	0.87	ET	0.76	T	0.87	–	–
September	–	–	P	0.72	P	0.6	T	0.81	–	–
October	P	0.7	P	0.82	–	–	T	0.76	–	–
November	P	0.75	P	0.91	–	–	P	0.82	–	–
December	–	–	P	0.96	P	0.68	P	0.79	–	–
Year	P	0.86	P	0.96	P	0.89	P	0.91	ET	0.88

Remarks: –: None of the correlations was significant. Soil texture at the 115 meteorological stations was distributed as follows: sand: 16; sandy loam: 9; loam: 63; clay loam: 21 and clay: 7 stations. R^2 = coefficient of determination

selected periods (month, growing season [March–November period) and year). Relationships that have reached the P = 0.01 significance level, as well as the coefficient of determination (R^2) are presented in Table 2.

In winter, ET was only a few mm because of the low temperatures. In December, which is the warmest winter month, the relationship between ET and T was significant, while in January such was lacking. In February a significant relationship was found only in the case of sandy loam. In March, VK came close to VK_{sz} (see Fig. 3A.), therefore further precipitation did not influence evapotranspiration. With the increase of T, ET also increased, from March to May ET rose from 15 mm to 90 mm. This increased ET was higher than P, therefore VK decreased in this period. In spring, the ET/T relationship characterizing R^2 value was around 0.87 on the average, but it could reach 0.95, which means a strong relationship, taking into account that ET depends on both the VK and T. There was a significant decline in the water content of sandy soils up to June (see Fig 3A.), as during this period ET was determined by VK. In July and August the soil was almost completely dry, therefore the main factor was P in this period. In these months, almost all precipitation evaporated because of the high temperatures. In September, VK was close to VK_h for all five soil texture classes. In this period ET was lower than in summer, therefore there was a strong correlation between ET and P. In October and November, both the VK and P were large, so ET was determined by T, which decreased. In the case of annual ET, P is the main factor.

Let us now investigate the VK! In March, due to the high VK values, no significant relationship was found. In April, R^2 values were around 0.6, primarily because of the high VK values. In summer, due to the constant decline of VK, it became increasingly dependent upon ET and T. In autumn, VK was again determined by P. In September, when the VK values were the lowest, the R^2 values were somewhat lower than in October and November. The R^2 value for loam in October and November was so low that the relationship between VK and P was insignificant. For annual VK, P is again the main factor.

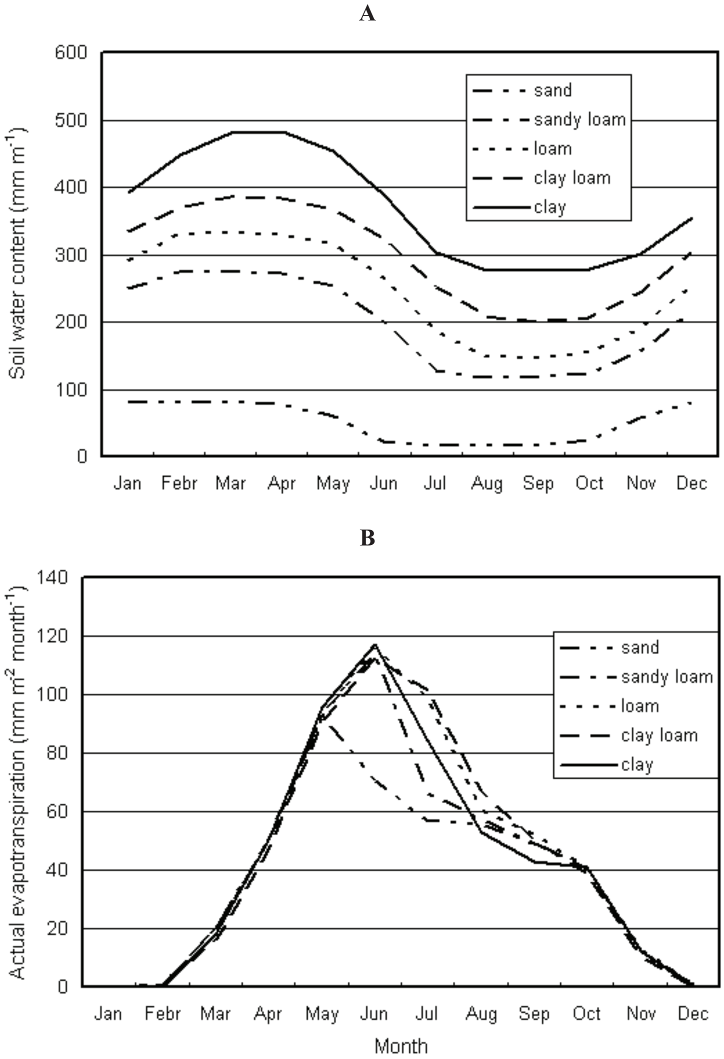


Fig. 3
Annual course of soil water content (A) and actual evapotranspiration (B) for the soil texture categories: sand, sandy loam, loam, clay loam and clay

The annual course of soil water content and evapotranspiration

The annual course of soil water content (VK) and actual evapotranspiration (ET) according to different soil texture classes is presented in Fig. 3.

Soil texture classes of the 115 meteorological stations are distributed as follows: sand on 16, sandy loam on 9, loam on 63, clay loam on 21 and clay on 7 stations. The annual change of VK is very similar to that obtained in the verification tests for VK (see Fig. 2.). Sand differentiates from other soil texture classes, presumably because of its low water holding capacity. The course of clay is the most striking: its spring maximum is higher than its value in January and the minimum value characteristic of the autumn drought is also higher than that of other soil texture classes.

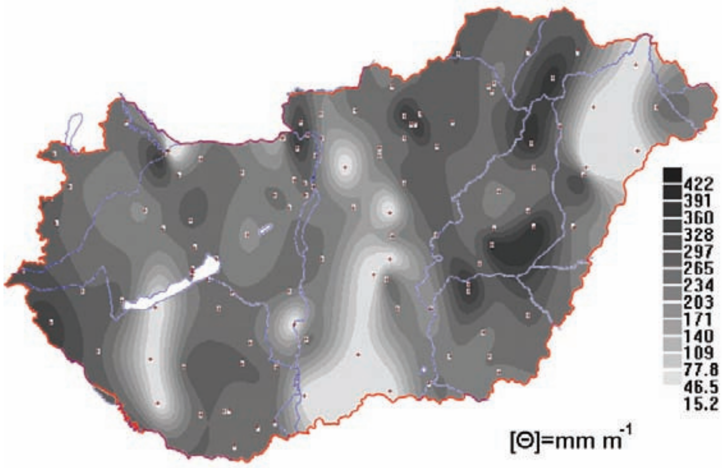
The annual course of ET is similar to that of T, with a maximum value in June and a minimum in January. In the case of sand, the maximum value occurs in May. ET decreases considerably from June to August, while from August to October the rate of decline is smaller.

Spatial distributions

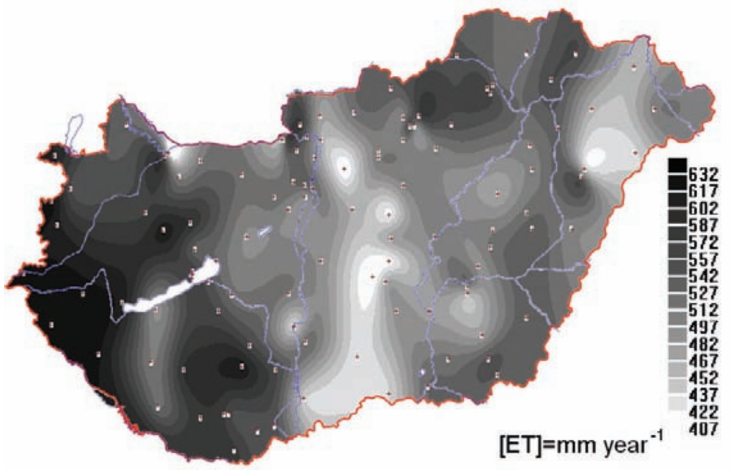
Spatial distribution of annual values. – Spatial distribution of the annual VK values (Fig. 4A) is greatly determined by the spatial distribution of the soil texture classes.

The lowest VK values occur on sandy, while the highest ones on clayey areas. On large sandy areas – as in the Nyírség, the Gödöllő-Hills, the Kiskunság Plain, the vicinity of Paks, the southern parts of Szigetköz, the Tapolca Basin, and the Inner Somogy region – the mean annual value of VK is 30–50 mm·m^{-1}. On clay

A



B



C

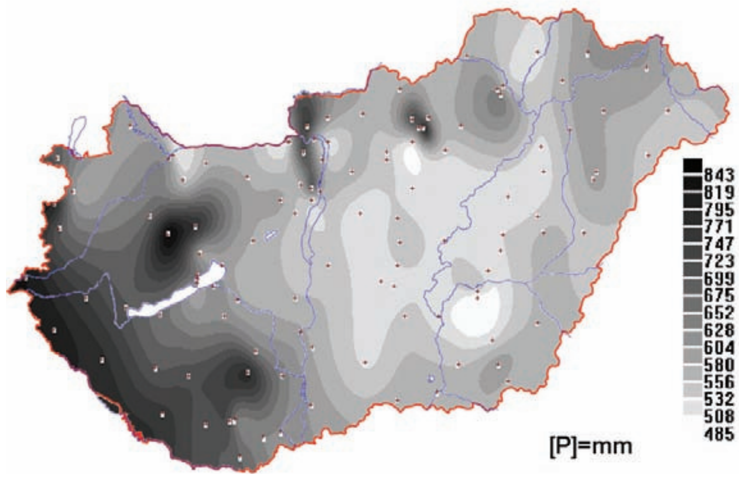


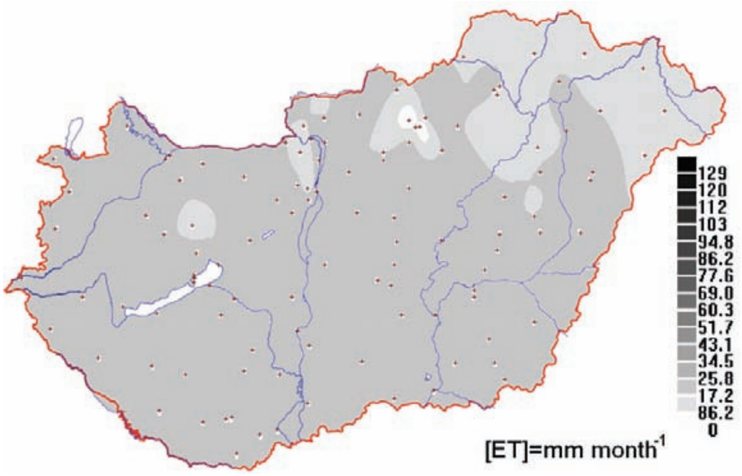
Fig. 4.
Spatial distribution of the mean annual soil water content [VK] (A), of the annual sum of evapotranspiration [ET] (B) and precipitation [P] (C) in Hungary

and clay loam areas – as in the Tokaj Hegyalja, the Taktaköz, the northern parts of the Hortobágy Plain, the Mátra, Börzsöny and Visegrád Mountains, the Dévaványa Plain, the Hajdúság Plain, southern parts of the Nagykunság Plain and western part of the Békési Plain – VK is 320–390 mm·m^{-1} on the average. VK is 280–300 mm·m^{-1} on the loamy areas of the Zselic Hills and the Zala Hills. This value is somewhat higher than the VK values found in some other loamy areas, which is primarily due to the differences in precipitation (see Fig. 4C).

The spatial distribution of the annual sum of evapotranspiration (ET) (Fig. 4B) depends both on soil water content and precipitation (Table 2, Fig. 4C). The spatial distribution of minimum (407–470 mm·year^{-1}) and maximum (580–630 mm·year^{-1}) ET values roughly corresponds to the spatial distribution of the lowest and the highest values of VK, respectively. Evapotranspiration in the Körös-zug Jászság Plain and Csepel Plain regions is lower than that of other regions belonging to the same soil texture class because of the small precipitation. In the southwestern part of Hungary where there is more precipitation, the annual sum of ET is about 600 mm·year^{-1}.

Spatial distribution of monthly values. – In spring ET is determined by T (see Table 2). In March ET is between 5 and 25 mm·month^{-1} (Fig. 5A).

A



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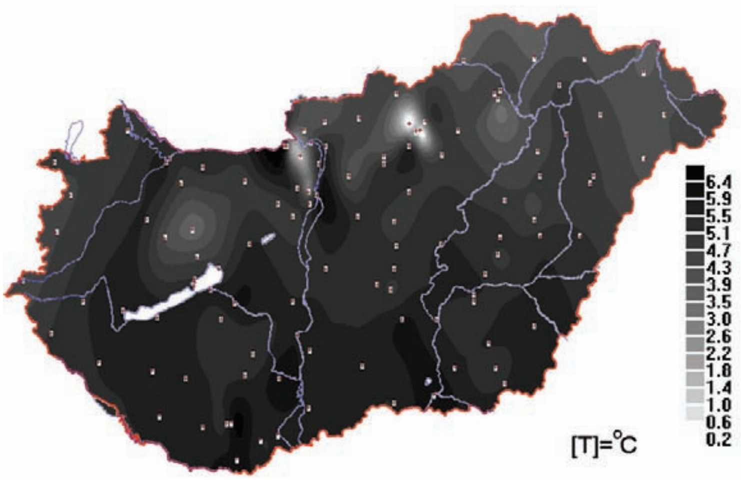
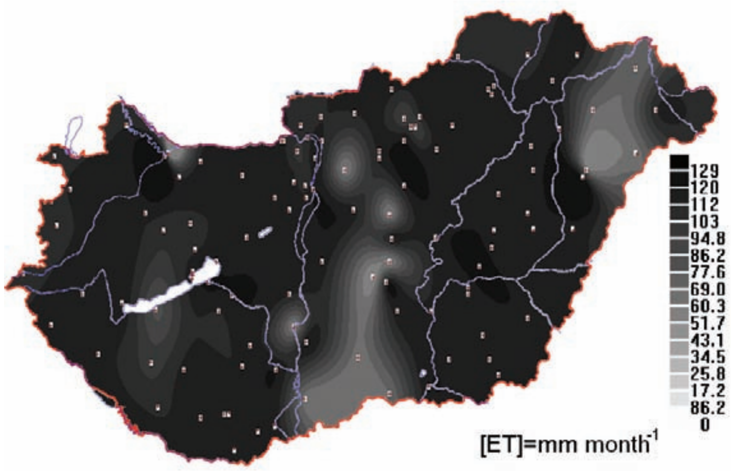


Fig. 5
Spatial distribution of actual evapotranspiration (ET) (A) and air temperature (B) in March in Hungary

The lowest ET values are located in the Mátra, the Visegrád and the Pilis Mountains and in the Miskolc-Gate region, while the highest ones are found in the sector between Szeged and Kiskunfélegyháza, in the Pest Plain, the Marcal Basin, the Mezőföld and the southwest region of Hungary – with the exception of the Tolnai ridge. Comparing the spatial distribution of ET and T in March (see Fig. 5), it can be seen that spatial distribution of the extreme values of ET and T is very similar.

In June the spatial distribution of ET and VK (Fig. 6A and 6B) is almost identical with the spatial distribution of the annual ET (Fig. 4B) and VK (Fig. 4A).

A



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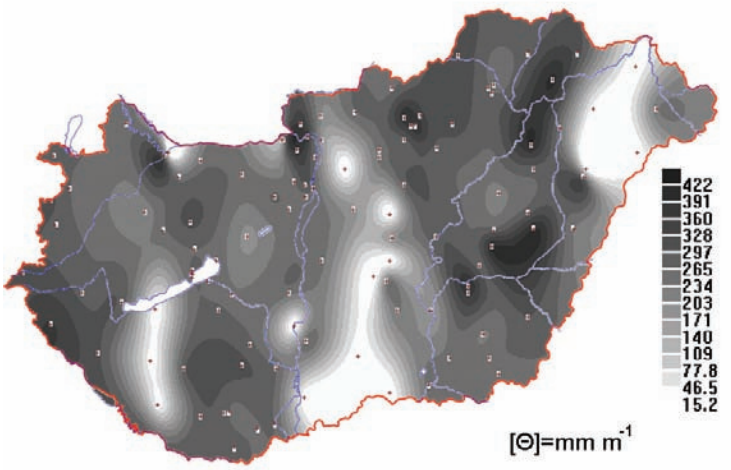

Fig. 6
Spatial distribution of actual evapotranspiration (ET) (A) and soil water content (VK) (B) in June in Hungary

The lowest ET values (40–75 mm·month^{-1}) are found in the Nyírség, the Pest Plain, the Kiskunság, the Illancs and the Inner-Somogy regions and the Tapolca Basin. The highest ET values occur in the eastern part of the Mosoni Plain, in the Sokoró Hill, the northern part of the Mezőföld, the southern part of the Hajdúság regions, in the Dévaványa and the Békési Plains. The spatial distribution of the extreme values of ET and VK coincide with each other to a great extent. This is not valid for all areas though, greater deviations also occur, for example in the Mátra Mountain (where ET is low because of the low temperatures and VK is high) or in

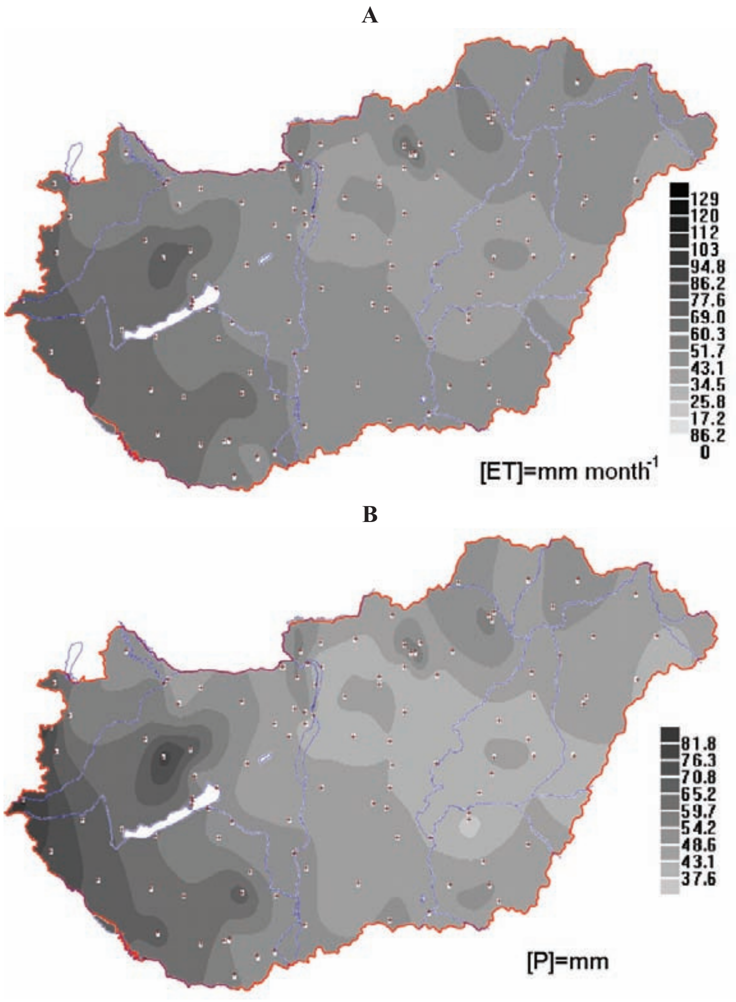

Fig. 7
Spatial distribution of actual evapotranspiration (ET) (A) and precipitation (P) (B) in September in Hungary

some places around Lake Balaton (where VK is low, while ET is high because of higher P values).

Fig. 3A shows that August and September are the driest months (having the lowest VK values). In the case of low VK values, even the smallest amount of precipitation (P) may cause great changes in ET. This is well illustrated by Fig. 7A and 7B, as the spatial distribution of ET (Fig. 7A) is extremely similar to that of P (Fig. 7B). In places with the lowest P values, ET values are around 40–45 mm·month^{-1}. Westward from Békés to Somogy county, ET increases with increasing P. The highest ET (around 60–85 mm·month^{-1}) occurs in the Mátra, the North-Bakony, the Mecsek Mountains and in the border region of Austria and Hungary.

Evaluation of the results

Mesoclimatological characteristics (seasonal changes, spatial distribution) of evapotranspiration in Hungary were amalyzed by using a modified THORNTHWAITE (1948) based model. In the modified Thornthwaite based model, in addition to potential evapotranspiration actual evapotranspiration is also estimated, taking into account its dependence on soil texture classes. The model is unable to distinguish between bare (uncovered) soil surface and vegetation. In the model, the vegetation is a uniform grass cover. Grass covered surface is accepted as a reference surface in evapotranspiration studies (SHUTTLEWORTH, 1991). The model calculates with a 1 m deep rooting zone and soil column.

The obtained annual mean values of VK are between 40 and 400 mm·year^{-1}. The lowest VK values occur on sandy soil areas irrespective of the spatial distribution of P. The highest VK values are found on clay soils, their spatial distribution, however, is also determined by that of P. The stronger the dependence of VK on the spatial distribution of P is, the finer the soil texture class is.

The gained annual mean sums of ET range between 400 and 650 mm, which is about 3–4-times higher than the annual mean of the available soil water content (130–180 mm). The spatial distribution of the annual ET and VK is very similar. It can be said that the spatial distribution of the annual ET is determined by that of the annual VK, which depends both on the soil texture classes and on the spatial distribution of the annual P. In spring evapotranspiration (ET) is potential and independent of the soil texture classes (see Fig. 3B) and its spatial distribution is determined by the spatial distribution of T. In autumn ET is determined by the low VK values (September) and T (October, November). In October and November ET is also independent of soil texture classes (Fig. 3B). In spite of this, in summer ET depends considerably on the soil texture classes and the spatial distribution of P.

The obtained results have not been confirmed by field measurements or satellite observations, however, they are in accordance with empirical expectations (for instance, dependence on soil texture classes and the spatial distribution of P). Nevertheless, it should be emphasized that this is the first investigation in which the ET/soil characteristics relationship has been analyzed on mesoscale in Hungary.

In Hungary evapotranspiration is – among surface factors – essentially determined by the relief, soil properties and vegetation cover. The effect of relief is indirectly taken into account via temperature and precipitation data. The effect of the soil is treated explicitly.

For the estimation of mesoscale evapotranspiration the model can be improved by an explict treatment of the relief. A model taking relief into consideration would make it possible to estimate the hydroclimate of Hungary on microscale (spatial resolution of a few km). Construction of such a model is one of the future tasks.

Summary

The paper deals with the mesoclimatological characteristics of evapotranspiration and soil water content in Hungary. Analysis is carried out using a modified version of the Thornthwaite model (THORNTHWAITE, 1948). Actual evapotranspiration is estimated as the product of the Thornthwaite's potential evapotranspiration PET and the β function of MINTZ & WALKER (1993). A second order implicit numerical scheme is used to estimate soil water content. The acceptability of the model is tested on a 21-year data series from the Agrometeorological Observatory in Debrecen.

The correlation between actual evapotranspiration (ET), soil water content (VK) and environmental factors is analyzed in detail.

The lowest annual VK values are obtained on sandy areas, irrespective of the areal distribution of the annual precipitation. The highest annual VK values are recorded on the clay areas, where the areal distribution of VK is determined by the areal distribution of annual precipitation. The dependence of the areal distribution of annual VK on the areal distribution of the annual precipitation increases from the coarser to finer soil texture.

The areal distribution of annual ET and annual VK are very similar. In spring, autumn and winter ET is independent of soil texture, but in summer it does depend on both soil texture and the areal distribution of precipitation.

Key words: actual evapotranspiration, soil water holding capacity, Thornthwaite's model, vegetation period, mesoscale

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