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Widening Gap of Land Evaporation to Reference Evapotranspiration Implies Increasing Vulnerability to Droughts in Hungary

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Abstract

Severe droughts of 2022 in Europe raise the question if one has sufficient knowledge and tools to predict and prevent such events. Analysis of 40 years of meteorological data for Hungary between 1981 and 2020 confirms significant upward trends with $p = 0.05$ in temperature, relative humidity, and net radiation. Shortwave net radiation has increased by 89.6 mm in water equivalent. Estimates of land evaporation and reference evapotranspiration also show a significantly increasing trend. The gap between them is widening with a significant trend in northeast Hungary. The demand (reference evapotranspiration) is increasing by 2.23 ± 0.3 mm yr^{-1}, while supply (land evaporation) by 1.64 ± 0.2 mm yr^{-1}. The opening gap can be interpreted as a decreasing stability of the energy distribution system, where water is the dominant energy transfer medium for climatic energy. This change could lead to an increased risk of droughts, a symptom of system underperformance. The climatic energy distribution process – a key environmental service - is shifting to a new operating point where more water would be needed to transport energy. These trends call for a process capability approach. Desertification cannot be stopped by chasing water use efficiency and using less water, but vice versa: water scarcity can only be eliminated by ensuring that there is sufficient water available for evapotranspiration. This will raise the priority for initiatives to design and implement a wide range of preventing actions, such as nature-based solutions and water retention measures.

Keywords

drought, complementary relationship of evaporation, climatic energy balance, hydrological cycle, atmospheric circulation

1 Introduction

Global warming is calling attention to the vital importance of water resources. Recent severe droughts across Europe have shown that scarcity of water may have huge negative impact on many aspects of one's life. While keen to maintain access to water for human-, industrial- and agricultural needs, one tends to underestimate the importance of water in the hydrological cycle as an energy transport medium [1, 2]. The IPCC 2019 Technical Report highlighted that the rate of warming is higher on the continents, compared to the overall rate of global warning [3]. This anomaly should heighten one's awareness that there might be good reasons for this difference, and one needs to pay more attention to understanding the forces that drive this change.

1.1 Key concepts

The energy distribution function of the hydrological cycle is well known by experts, however there is limited public awareness of this fact and about the magnitude of the climatic energy that is being distributed [4]. Evapotranspiration (ET) has a key role in transporting energy by picking it up as latent heat from the surface and deploying it in the clouds via condensation. Evapotranspiration is the driving force in sustainability on land [5, 6], and this subject is an emerging research area. Understanding the complexity of the process properly requires the cooperation of several disciplines: physics, biology, hydrology, meteorology, agriculture, forestry, economy, etc. Evapotranspiration can be described as a key environmental service, and this recognition promotes water to be a central element of circular economy models [7, 8].

The role of vegetation requires special attention in this service, as plants on one side are consumers of water for their own growth but on the other side, they are dominant contributors to local climate regulation via transpiration

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(therefore providing latent heat transfer). Deficiency in the provision of this service due to lack of water, or due to the lack of appropriate vegetation creates the symptom of the heat-island effects. This phenomenon has the same root cause in urban areas and in intensively cultivated agricultural lands [9, 10]. Recent global research on relative humidity trends has shown that vegetation flexibly adapts to external conditions, increases transpiration when more latent heat needs to be transported (due to higher temperature), but only to a certain extent. If the moisture supply to vegetation becomes limited, the stomata change mode of operation, limit transpiration, regulation cannot follow the demand for latent heat transport. The lack of evapotranspiration becomes a constraint [11]. Growth of interlocking areas with heat distribution restrains explains the changing trend in global evaporation. At around the beginning of this century, the increasing trend of global evaporation has halted [12].

1.2 Motivation

The view of evaporation gradually changes from a loss factor in the hydrological cycle to a key element of sustainability on land. Further on in this paper we use the terms evaporation or land evaporation for the phase change of water into vapor irrespectively from the source or process (evaporation from soil, road, transpiration by vegetation etc.), as a summary name like evapotranspiration, and use the symbol ET for it. Better understanding the inevitably important function of water in energy dissipation can help us to address sustainability from another perspective. Returning to square one, finding the root causes of desertification as one of the main environmental problems of civilizations opens a new path to research.

The process of evaporation can be described by the laws of physics where available energy and water define the constraints of the process. Actual evaporation depends on numerous local factors and makes it challenging to compare and qualify evaporation rates. Several evaporation components can be identified making any comparison a non-trivial task. A widely used term is reference evapotranspiration ET_0, the rate at which sufficiently available water is vaporized from a uniform vegetated surface, such as short grass.

Both ET and ET_0 can be estimated using the calculation algorithm developed for the complementary relationship concept of evaporation. The thermodynamic foundations of the method were identified by Szilágyi [13] and support the efforts to estimate evaporation using only a few standard meteorological variables (see Section 2.3). Changes in the global trends of evaporation and its components were identified recently [14]. The whole complexity goes beyond the scope of this work but assessing meteorological data and evaporation together may contribute to better understanding of the regulation process of energy distribution via evapotranspiration.

1.3 Scope of this study

The problem statement that can be concluded from the above briefing is that the ability of the environment to effectively participate in climate energy dissipation by controlling evaporation is weakened. This is a broad research area; this study focuses on a small subset of the problem. First: trends and spatial distribution of standard meteorological data are analyzed for Hungary, focusing on the parameters necessary to estimate evaporation. Second: land evaporation is estimated by the complementary relationship method and the results are validated with additional meteorological and hydrological data. Third: trends and spatial distribution of both the forcing variables and the resulting ET rates are assessed and compared to the reference evaporation, ET_0. Fourth: conditions for and occurrence of the 2022 droughts are investigated to see if it could have been foreseen based on the available meteorological and hydrological data.

2 Material and methods

Data presented in this study are from publicly available sources. After downloading the required data, they were preprocessed in MATLAB, including averaging, aggregation, and statistical trend testing. The resulting graphs and maps were also generated from MATLAB and visualized in QGIS.

2.1 Data sources

Meteorological data for the 40-year period of 1981-2020 are from the ECMWF ERA5-Land Monthly Averaged Dataset reanalysis database, downloaded from the Copernicus CDC Data Store (CDC) [15]. The selected area was from 16.1° E to 23.0° E and 45.7° to 48.7° N, respectively. Spatial resolution of the gridded data is 0.1° × 0.1° (approx. 9-km × 11-km cell size). The whole area of Hungary is covered by 1233 grid points. Cells not falling to the area of Hungary in the 30 × 69 matrix were masked out. Temporal resolution of the meteorological data is monthly for each parameter used. One single datafile was downloaded from CDC for all the selected variables between 1981 and 2020 [air temperature:

"t2m"; dew-point temperature: "d2m"; net radiation components (short- and long-wave): "ssr" and "str"; wind speed components (streamwise and crosswind): "u10" and "v10"; as well as surface pressure: "sp"]. These input data were used for estimating land evaporation. Meteorological data for crosschecking the input data set are from the gridded database of the Hungarian Meteorological Service (OMSZ), downloaded from the Gridded Data Series site [16] (relative humidity: "u"; air temperature: "ta"; precipitation: "r"; and global radiation: "sr").

Estimated evaporation was validated using runoff data for selected watersheds in Hungary (Marcal, Zala, Kapos, Rinya, Zagyva, and Tarna rivers). Data were provided upon request from the General Directorate for Water Management (OVF) in Hungary, through the Data Provisioning Service [17]. Ancillary soil moisture information was downloaded from the web application of the Directorate "Operational Drought and Water Scarcity Management System" [18].

2.2 Pre-processing the data

Annual averages were calculated from the ERA5-Land monthly input data in MATLAB for further processing. For each of the meteorological parameters, data were aggregated/averaged to annual values for each cell and each year resulting in a three-dimensional matrix.

This allowed to create a total average map for the whole period, as well as to calculate the trendline for each cell, and based on the average annual difference create a trend map showing the accrued differences cell by cell for the whole 40-year period (steepness multiplied by the number of periods).

In each year the total annual average was also calculated over Hungary, and based on this, a linear trend-line of annual averages was constructed. For data from the Hungarian Meteorological Service the approach was the same, only an additional step was required at the beginning to aggregate/average daily data to monthly data.

Six-hourly runoff data for the selected catchment areas were imported to Excel. Once the data were aggregated into monthly values (using neighboring average values for the few missing data points), the total annual runoff was created for hydrological years.

2.3 Method

The physical process of terrestrial evaporation for a sufficiently large surface is influenced only by a few simple meteorological parameters: air temperature, relative humidity (or dew-point temperature), pressure, net radiation at the surface, and wind speed. Once the five meteorological input parameters were converted into the required format and physical dimensions, actual land evaporation (ET) and reference evapotranspiration (ET0) were calculated using the complementary relationship (CR) method of Szilágyi [13] developed from the original conceptualization of Bouchet [19].

The unique advantage of the CR method is that inhomogeneity of the surface is integrated by these parameters, so one can avoid the complexity of using other parameters in the estimation of evaporation (e.g., precipitation, the local effect of vegetation, land surface temperature, soil moisture etc.). There is no need for precipitation data with the CR method. Air temperature and relative humidity define the ability of an air parcel of how much vapor it can "pick up" due to available energy. The source of moisture is not relevant in this context (could be precipitation, groundwater, or soil moisture). All the local differences are smoothed into the gridded meteorological variables over an area more than about one km^2 and temporal averaging of five days. Monthly average data with a spatial resolution of 9 by 12 km used in this work meet these conditions.

Existence of a linear trend for each input parameter was checked with the Mann-Kendall test at a 5% significance level, using a script from the MATLAB File Exchange Library [20].

Ma and Szilagyi [21] provide a detailed description of the calculation process (variables, physical constants) within the CR, as well as a pseudocode. The evaporation estimation code used in this study was written in MATLAB based on the pseudocode available in [21] (also referred to as the CR2019 method in this article).

The concept of the CR method is that it considers the latent heat difference between a small wet patch and a regionally large wet surface, assuming that the same net radiation and wind speed are applicable at both places. The actual land evaporation rate is nonlinearly related to this difference. The method requires to calculate the evaporation rate of a small wet patch (ET_0) via the Penman equation [22], and that of a large wet surface (ET_w) via the Priestley-Taylor (PT) equation [23]. For more details of the calculation see [21]. The advantage of the method is that it can be used in all hydroclimatic environments where horizontal advection of energy and moisture is not overwhelming as is the case along seashores of hot deserts. Its sole parameter, the Priestley-Taylor α may require calibration but can also be set without it, as discussed in [21].

3 Results

3.1 Trend analysis of meteorological data

Trends in annual averages for the five key meteorological variables driving evaporation (see Section 2.3) were analyzed for 1981–2020. Three variables display significant trends (air temperature, relative humidity, and net radiation), while the other two (wind speed and surface pressure) were not showing any (Table 1). Details are presented in the following subsections.

3.1.1 Air temperature at 2 m

Annual average temperature at 2-m height expresses an increasing trend verified by the MK test (Fig. 1 and Table 1). In the following graphs, we give the R^2 value for the linear regression lines, which shows how close the data points are to the trend line. R^2 values are always between 0 and 1 (where 1 indicates a perfect match). Southwest Hungary displays the smallest increase of temperature (but still reaching 1.5 °C over the 40-year period), while the highest increase can be found in Northeast Hungary. This may seem to have an impact on other parameters (see Section 3.3).

3.1.2 Dew-point temperature at 2 m, relative humidity

The MK trend test confirms increasing tendency of dew-point temperature at 2 m (Fig. 2 and Table 1). The lowest increase can be found in the montain range in northern Hungary.

Increasing dew point temperature at 2 m indicates a shift of the saturation point (increased water vapor content near the surface). Relative humidity, however, depends also on the actual temperature. Both air and dew-point temperature are available in the ERA5-Land database, so

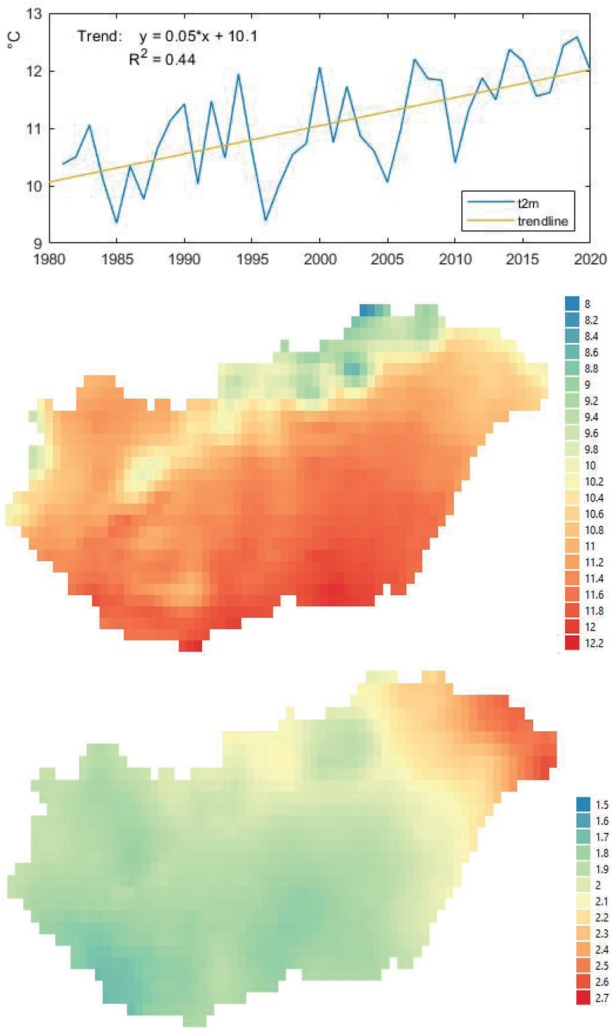

Fig. 1 2-m air temperature (t2m in °C) in Hungary (1981–2020). Annual averages and the 40-year trendline (top), spatial distribution of the 40-year annual average (middle), and the accrued change (bottom). Data source: ECMWF ERA-5 Land

relative humidity can be calculated with the Tetens formula (see e.g., in [21]). The resulting trend of relative humidity is decreasing. This is also confirmed by data from the Hungarian Meteorological Service (OMSZ), illustrated in Fig. 3. The greatest decline in annual average relative humidity can be seen in Northeast Hungary (3–5%).

Table 1 Mann-Kendall trend test results for all parameters at $p = 0.05$ significance level (95% probability)

Variable	*p*	Trend	Figure/ Section
Air temperature	0.00	Significant	Fig. 1
Dew-point temperature	0.00	Significant	Fig. 2
Relative humidity	0.02	Significant	Fig. 3
Net radiation	0.01	Significant	Fig. 4
Net shortwave radiation	0.01	Significant	Figs. 5, 6
Net longwave radiation	0.99	No	Figs. 5, 6
Air pressure	0.27	No	3.1.4
Wind speed	0.14	No	3.1.5
Land evaporation (ET)	0.03	Significant	Fig. 8
Reference evapotranspiration (ET_0)	0.04	Significant	Fig. 8
Evaporation gap ($ET_0 - ET$)	0.46	No	Fig. 9
$ET_0 - ET$ (Northeast Hungary)	< 0.05	Significant	Fig. 9

3.1.3 Net radiation

Net radiation was derived from the ECMWF ERA5-Land database as the sum of net short- and long-wave radiation.

The total of the two net energy components represents the net energy available at the surface (following the convention using positive sign for incoming and negative for outgoing radiation). The MK test confirms an increasing trend for net radiation (Table 1). The average change in net radiation over the 40-year study period is around 224 MJ/m^2 or 89.6 mm in water equivalent of evaporation (Fig. 4).

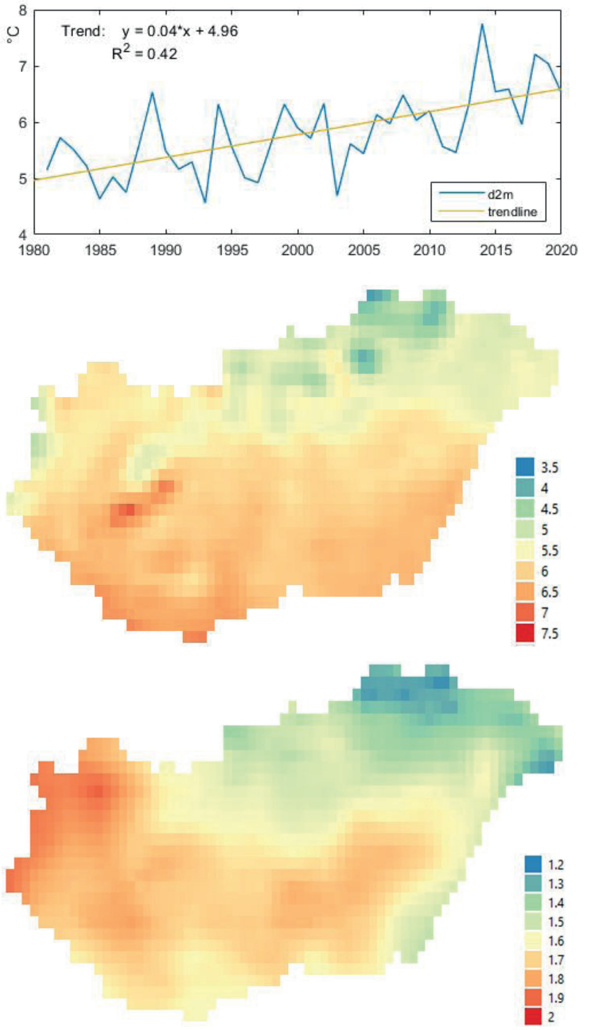

Fig. 2 2-m dew-point temperature (d2m in °C) in Hungary (1981–2020). Annual averages and the 40-year trendline (top), spatial distribution of the 40-year annual average (middle), and the accrued change (bottom). Data source: ECMWF ERA-5 Land

Conversion was performed by a latent heat of evaporation value of 2.5 MJ/kg and water density of 1 kg/dm^3. One can ask: which component is dominating the change? The 40-year series of the annual shortwave component shows a clearly increasing trend (Fig. 5 and Table 1). The net longwave radiation expresses no significant trend (Fig. 5).

On the spatial distribution of the short-wave net radiation, zonality can be recognized (more incoming radiation at the lower latitudes), while on the shortwave component elevation influences the patterns. In both components Northeast Hungary displays the largest changes (Fig 6).

3.1.4 Air pressure

Air pressure at the surface does not show any significant trend (Table 1), as calculated from the ERA-5 Land data for the 1981–2020 period. Avarage annual pressure is between

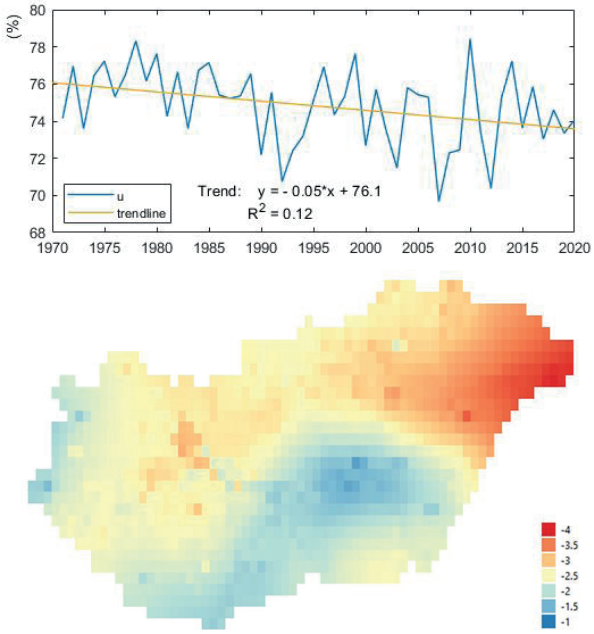

Fig. 3 2-m relative humidity (u in %) in Hungary (1971–2020). Annual averages and the 50-year trendline (top), spatial distribution of the accrued change (bottom). Data are from the Hungarian Meteorological Service (OMSZ)

998 and 999 hPa. Spatial distribution of the areas with lower surface pressure coincides with the montainous areas of the country.

3.1.5 Wind speed and prevailing wind direction

There is no significant trend in wind speed at 2 m, as shown by the MK test (Table 1) for the ERA5-Land data. Spatial distribution displays slightly higher wind speed in Northwest Hungary, where the prevailing Atlantic air masses reach the country. Wind speed at 2 m (U2m) was determined from ERA5-Land 10-m wind data components of u10 and v10 by first determining the magnitude at 10 m (U10m) as in Eq. (1):

$$U10m = \sqrt{\left(\left(u10\right)^2 + \left(v10\right)^2\right)}, \quad (1)$$

then scaling to 2 m with a power-function [21] in Eq. (2):

$$U2m = U10m * \left(\frac{2}{10}\right)^{\frac{1}{7}}. \quad (2)$$

3.2 CR-estimated evaporation trends

The analysis in Section 3.1 has indicated that three out of the five input meteorological variables (air and dew point temperature and short-wave radiation) have a significant trend, which thus also emerges in the evapotranspiration estimates (Table 1 and Fig. 7). Calibration of the

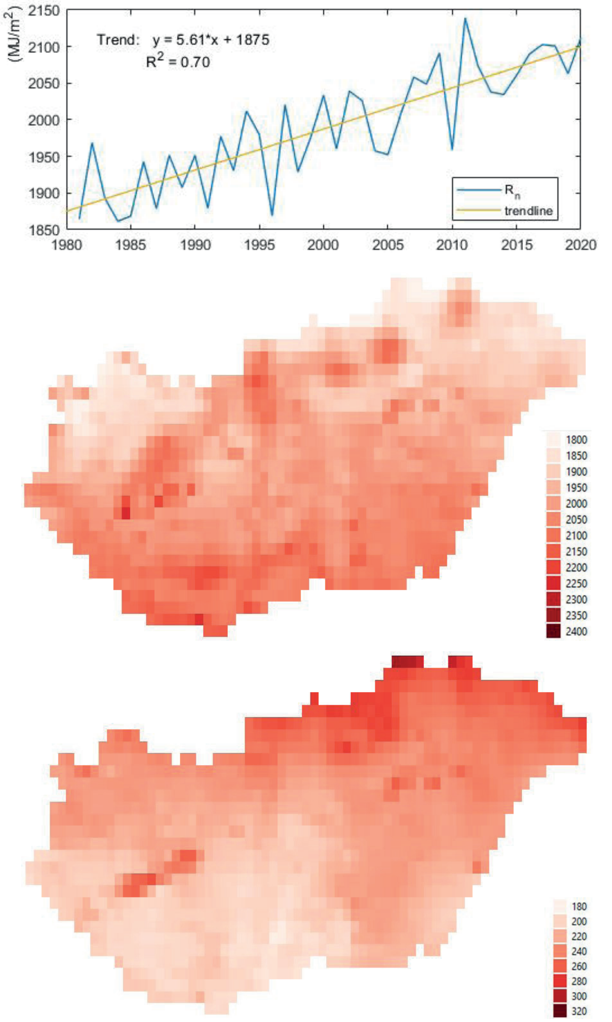

Fig. 4 Net radiation (Rn in MJ/m^2) in Hungary (1981–2020). Annual averages and the 40-year trendline (top), spatial distribution of the 40-year annual average (middle), and the accrued change (bottom). Data are from ECMWF ERA5-Land

Priestley-Taylor α parameter and validation of the results were based on precipitation data from OMSZ and runoff data from OVF (see Section 2.1). All data are annual averages for hydrological years during the period 2000-2008. The reason to select this calibration period was to make the calculations comparable with the result of a similar complementary relationship method called CREMAP [24]. Calibration of the CR2019 method yields $\alpha = 1.18$ (Table 2).

Other factors were not considered in the nine-year water balance. Water bodies (lakes, rivers) evaporate more than land surfaces, but their combined area is small compared to the size of the watersheds.

Difference between calculated evaporation and estimated evaporation from precipitation and runoff is below 10% for each catchment. Uncertainty of calculation is estimated to be within this ±10% range. Trends in groundwater levels were not considered either, as average annual such change is typically small (especially when multiplied by the porosity value to obtain corresponding

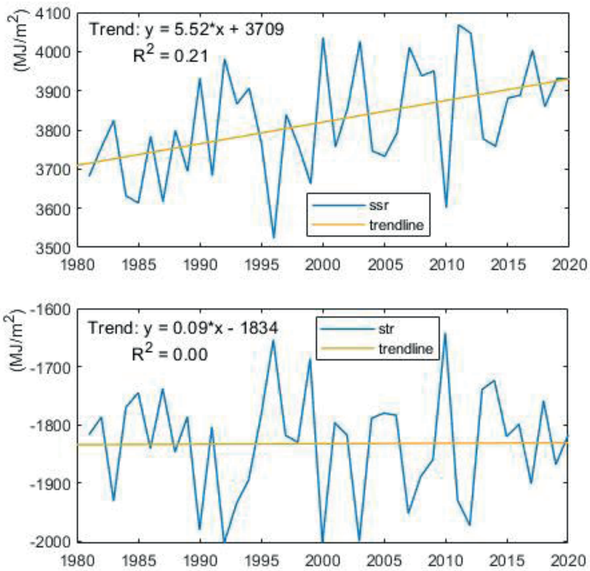

Fig. 5 Annual averages and the 40-year trendline of the net radiation components in Hungary (1981–2020). Net shortwave radiation (ssr in MJ/m^2) at the top, and net longwave radiation (str in MJ/m^2) at bottom. Data source: ECMWF ERA5-Land

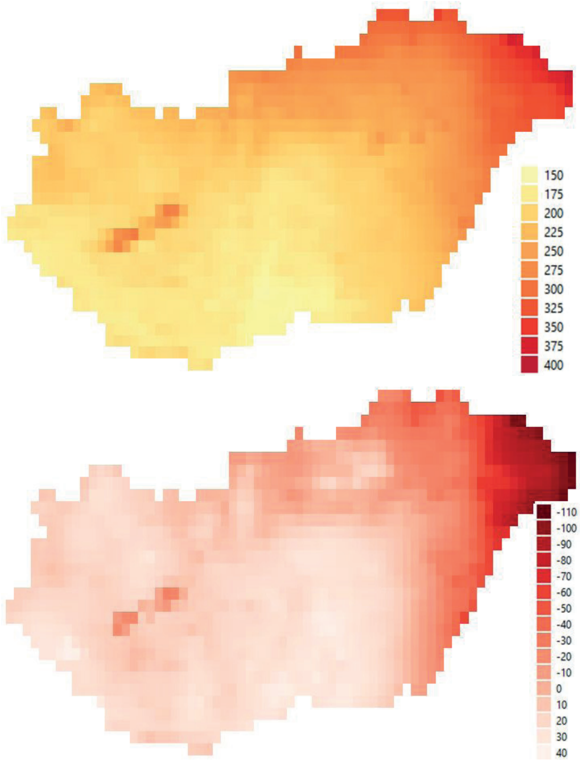

Fig. 6 Spatial distribution in accrued changes of net radiation components (MJ/m^2) in Hungary (1981–2020). Net shortwave radiation (top), net longwave radiation (bottom). Data source: ECMWF ERA5-Land

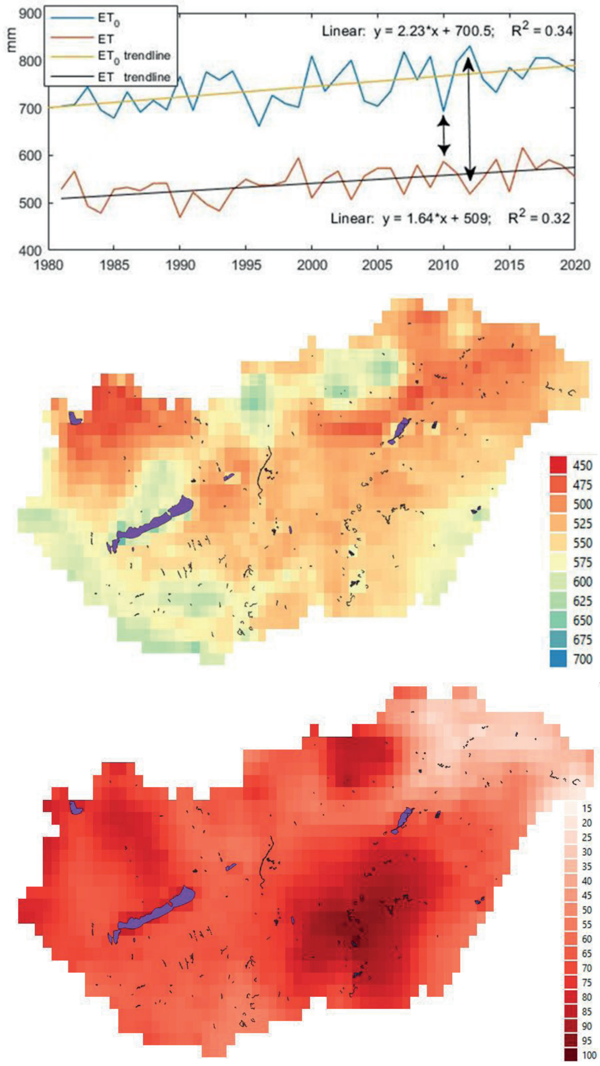

Fig. 7 Reference evapotranspiration (ET0) in Hungary (1981–2020) compared to land evaporation ET values (top). Two-way arrows on the trend chart between ET and ET0 point out the complementary relationship and feedback mechanism between the two variables. Spatial distribution of the 40-year annual average estimated land evaporation ET in mm yr^{-1} by the CR2019 method (middle) and the accrued change (bottom)

Table 2 Calibration/validation of the watershed-averaged annual mean evapotranspiration (ET) rates

2000–2008 (hydrologic years)	Kapos	Zala	Rinya	Marcal	Zagyva
Precipitation (P, mm)	647	627	680	618	566
Runoff (R, mm)	70	65	97	41	44
Water-balance (P–R) ET (mm)	577	562	583	578	523
ET from CREMAP	547	na	na	547	520
Present ET method	567	571	584	536	547
Difference between present ET and water balance	-1.9%	1.4%	-0.1%	-7.3%	4.5%

water depth), and the methods required are outside of the scope of this study (gravimetry, ground water monitoring systems). Their influence on the ET estimates is therefore assumed to be negligible. Note, noticeable groundwater level changes in the Danube-Tisza interfluvial sand plateau region have been reported by several authors over the past 50 years [25, 26], but the watersheds employed for calibration of the CR are outside of this region.

Estimations of land evaporation (Table 1 and Fig. 7) and reference evapotranspiration rates (Fig. 8) show significant increasing trend. Note, higher values of reference evapotranspiration occur when the land evaporation is lower.

3.3 Interpretation of the results

Now, one can have a closer look at the gap between reference evapotranspiration (ET_0) and land evaporation (ET). The difference between the annual averages of the two variables shows no significant trend.

The spatial distribution of the 40-year average gap (ET_0 -ET) was calculated as 40-year average reference evapotranspiration less 40-year average land evaporation cell by cell and is visualized on the map in Fig. 9. Performing the trend test for all cells in Hungary individually, one can see that there is a significantly increasing gap (at the 5% significance level) between reference evapotranspiration and estimated land evaporation for some cells, highlighted in dark black on the small map inset in the lower right corner of Fig 9. The pattern of these cells shows similarity to the map of air temperature, net radiation, and relative humidity. The changes are the highest in Northeast Hungary, where the trend of the gap is significant. This finding coincides with the analysis of air temperature data from the Hungarian Meteorological Service, too [27], pointing out that the increase of temperature is faster in this region.

The 40-year annual mean values and accrued trends for the study period 1981–2020 are summarized in Table 3. Both land evaporation (ET) and reference evapotranspiration (ET_0) have increased with significant trend, but reference evapotranspiration increased faster. A gap is opening.

Table 3 Summary of annual land evapotranspiration (ET), reference evaporation (ET_0) and precipitation rates in Hungary (1981–2020). Mean annual value and the 40-year accrued in the trend

Variable	40-yr mean		40-yr accrued value in trend	
	(mm)	(km^3)	(mm)	(km^3)
ET	543	50.5	66	6.1
ET_0	746	69.4	89	8.3
P	688	64.0	105	9.8

Trend of precipitation is also presented in Fig. 8. from 2 data sources. The rate of increase exceeds the rate of increase in estimated evaporation.

3.3.1 Demand–supply gap analysis of evaporation

The annual mean value of the estimated land evaporation (ET) is 543 mm with an accrued increment of 66 mm. The same for reference evapotranspiration (ET_0) are 746 mm and 89 mm, respectively. The volume of water in Lake Balaton is around 2 km^3, and based on this figure, it can be concluded that annual evaporation in Hungary increased by three Balaton volumes between 1981 and 2020, and the reference evapotranspiration by a factor of four, meanwhile the gap between evaporation and reference evapotranspiration (from Fig. 9) has also increased by about the amount of water in lake Balaton.

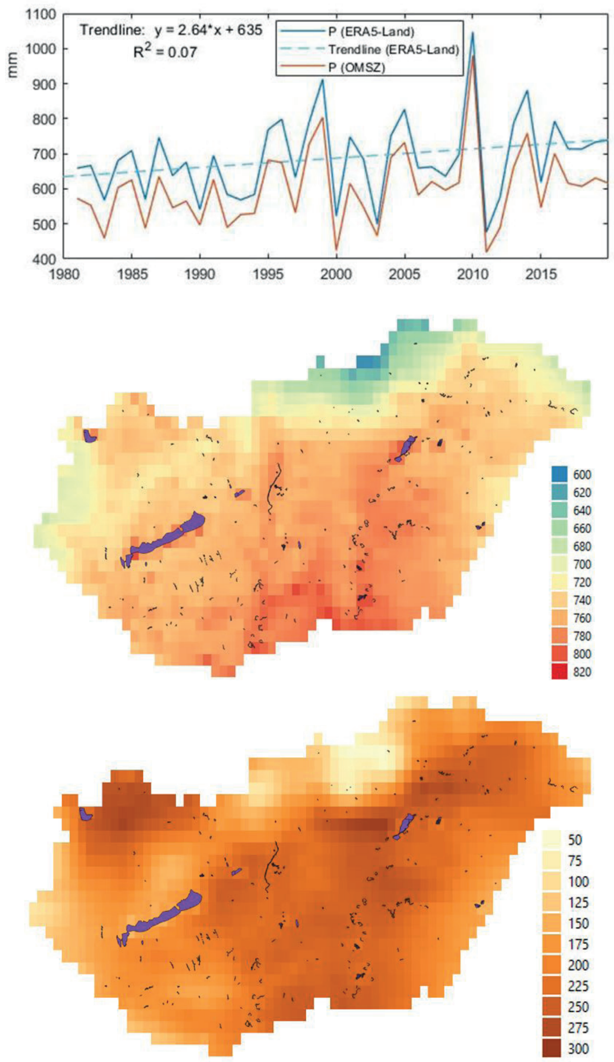

Fig. 8 The 40-year trendline (1981–2020) of annual precipitation (P) in Hungary (top). Spatial distribution of the 40-year annual average reference evapotranspiration ET_0 (middle) and accrued change in ET_0 (bottom)

Trend of reference evapotranspiration for the Carpathian region was estimated by the Penmann-Montieth method in recent research, using the FAO algorithm [28]. The increase was in the range of 40-125 mm from 1970 to 2010 with a slope 0.86 mm yr^{-1}. The rate of change 1–1.5 mm yr^{-1} for Hungary in the study is in line with our calculations.

Precipitation shows an increasing trend (Fig. 8) similar to estimated land evaporation. These two variables display similar annual fluctuations (Fig. 9) demonstrating the relationship between them. In most of the cases annual precipitation seems to be sufficient to supply the demand for land evaporation, however there are some years with deficit. This relationship requires further investigation.

4 Discussion

The opening gap between land evaporation and reference evapotranspiration can be interpreted as a decrease in the stability of the energy distribution system.

Note that the concept of water demand is generally used to describe the needs of society including industry and agriculture. In this consumer centric context, supply refers to how water resources are accessed. Paradoxically, understanding the climatic energy distribution process requires a change of perspective and terminology. The demand for

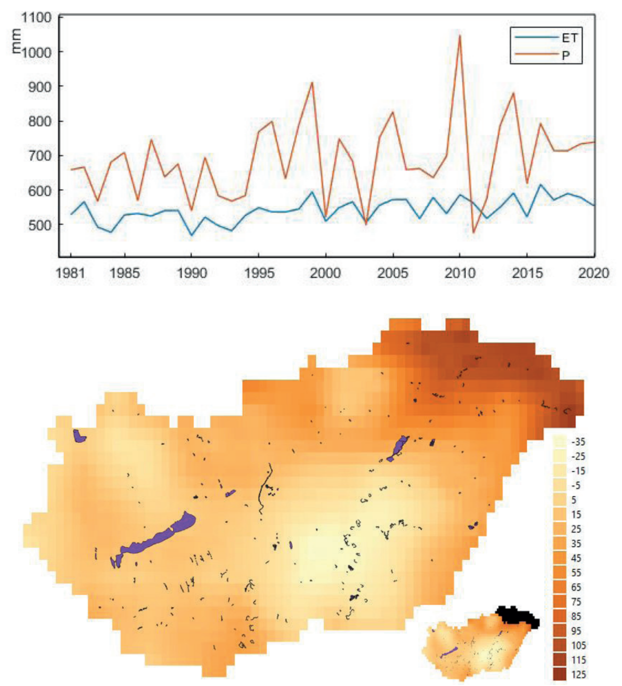

Fig. 9 Comparing annual precipitation (P) and estimated land evaporation (ET) values in Hungary (top). The 40-year annual average spatial distribution of the gap between reference evapotranspiration (ET_0) and land evaporation (ET) in mm (bottom). The dark black area on the map inset (bottom right) indicates cells with a significant increasing trend

water is determined by the amount of energy to be transported, while supply is represented by evapotranspiration performing the bulk of the task.

4.1 The working point of climate regulation

Sušnik et al. [29] showed how intensive land use changes the operation of the hydrological cycle coupled with atmospheric circulation, highlighted the regulatory features of the landscape (Fig. 10) and urged the implementation of water retention measures (WRMs). In the trend plot between ET and ET_0 (Fig. 8), the two-way arrows show the dampening effect of the higher evapotranspiration (ET), which reduces water demand (ET_0). The increasing trends and the growing gap can be interpreted as shift in the working point of the climate energy distribution process, where more water would be needed to transport energy.

Restoring the landscape could improve the efficiency of the climate regulation system by moisture recycling [30] and halt further shifts in its operations.

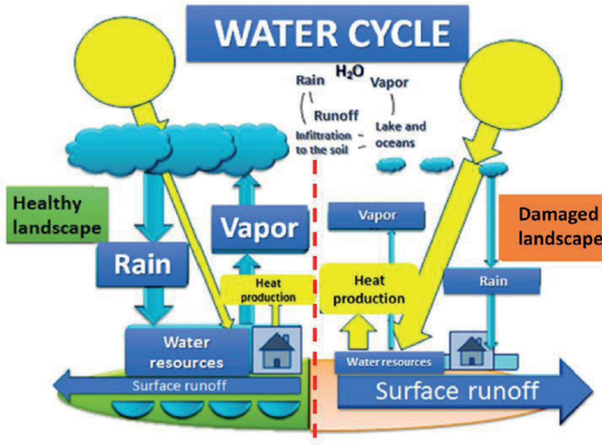

Fig. 10 Terrestrial climate regulation concept integrating the land-atmosphere feedback and water cycle. Source: Sušnik et al. [29] adopted from Kravčik et al. [6]

5 Conclusions

Land evaporation has increased in Hungary at a rate of 1.64 mm yr^{-1} in the last four decades. Reference evapotranspiration has increased faster, at 2.23 mm yr^{-1}. The opening gap between supply (land evaporation) and demand (reference evapotranspiration) raises concerns.

On the one hand, strategic questions need to be addressed, such as how to refine existing models and understand changes in the climate energy distribution process better, and on the other hand, operational questions, such as how to deal with weather extremes, such as droughts and avoid negative consequences. An interdisciplinary functional model advocates an emphasis on the importance of vegetation [31]. Deteriorating trends could bring us closer to a turning point where the mitigation capabilities of the landscape are not sufficient to keep the energy exchange process within an acceptable range. Analysis of the 2022 drought has shown that local, regional, and global processes are interconnected, and a positive feedback has escalated the severity of the drought [32].

Extension of this research would contribute to clarify what actions are needed to avoid more frequent weather extremes and stabilize the climatic conditions. Wider scope in time and space (e.g., ERA5-Land data are available now from 1950), analysis of additional variables/parameters, evaporation/transpiration ratio and higher resolution could be the next steps in the research.

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