Article

Potential evapotranspiration of managed grasslands - a climate change lysimeter study

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Abstract:
1. Evaluate default PET models
- scatter plot of all - maybe tudi gostote - mean monthly maybe - quantile-quantile plots([1]) - changes in median and interquartile range for projected PET series(([1]) 2. Evaluate calibrated PET models - scatter plot - calibration efficiency [1] 3. Implication/evaluation of elevated CO_2 in PET models
4. Implication/evaluation of warming in PET models
6. Implication/evaluation of combined effect of warming and elevated CO_2 in PET models
7. Uncertainty of hydrological model parameter selection 8. Uncertainty in PET model selection [2] 9. sensitivity of uncertainty 10. How large are uncertainties in future projection of reference evapotranspiration through different approaches? [2] [3], [4], [5], [6], [7], [8], [9]
8. Conclusion

Keywords: keyword 1; keyword 2; keyword 3 (list three to ten pertinent keywords specific to the article, yet reasonably common within the subject discipline.)

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0. Objectives

- Evaluate PET calculation methods for the present and future
- Uncertainty in PET methods
- Third bullet

1. Global Radiation data
ZAMG no data from (2018-03-16 till 2018-03-21
BOKU ERROR data for global rad from 2017-

2. Should I take LAI or height for PET calculation as LAI measurement do not fit with the cuting dates

3. In what time period should i observe PET?
3.1 Should I compare whole year or vegetation period?
3.2 Should I compare on same dates or start vegetation period/cuts
3.3 Vegetation period from start of vegetation till end of vegetation?

1. Introduction

[10] - higher PET with managed grasslands and [11]

2. Evaluation of PET models(Materials and methos)

2.1. Previous research

Sensitivity to erros in potential evapotranspiration input [12] [13] and [14](z0 = 1 for meadow grass)(details of computation)(Blaney-Criddle-only mean T, Jensen-Hasie [15]-solar radiation with T) compared 9 PET methods using onsite meteo data (PEnman with empirical wind function applicable to a short grass with rougness coef of 1cm): [16]-sensitivty of PEnman

$$f(u) = 0.35 + 0.0035 * u_2 \quad (1)$$

Search for best PE formula [17], [18]

2.2. Used PET models

Data notations and units

PE	potential evapotranspiration (mm day^{-1})	u	wind speed 2m above soil surface (m s^{-1})
Δ	Slope of vapor pressure curve (kPa $^{\circ}C^{-1}$)	T_a	air temperature ($^{\circ}$C)
λ	latent heat of vaporization (MJ kg^{-1})	T_d	dew point temperature ($^{\circ}$C)
ρ	water density (=1000 kg L^{-1})	R_e	extraterrestrial radiation (MJ $m^{-2}day^{-1}$)
γ	psychrometric constant (kPa $^{\circ}C^{-1}$)	R_g	global short-wave radiation (MJ $m^{-2}day^{-1}$)
e_s	saturation vapour pressure (kPa)	R_n	net solar radiation (MJ $m^{-2}day^{-1}$)
e_a	actual vapour pressure (kPa)	DL	day length (h day^{-1})
r_a	aerodynamic resistance (s m^{-1})	α	surface albedo
r_s	surface resistance (s m^{-1})	J_D	Julian day
k	monthly consumptive use coefficient (=0.85)	p	percentage of total daytime hours

Table 1. PET Computations

PET method	Equation	Coeff. to calibrate
Blaney-Criddle [19]	$PE = kp(aT_a + b)$, with a=0.46, b=8.13	k, a, b
FAO-PM ET_0 [20]	$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T_a+273} U_2(e_s - e_a)}{\Delta + \gamma(1+0.34u_2)}$	/
Hargreaves [21]	$PE = a(T_{max} - T_{min})^{0.5}(T_{mean} + T_x)\frac{R_a}{\lambda\rho_w}$	a, T_x
	with a=0.0023 and T_x=17.8	
Jensen-Haise	$PE = \frac{1}{\lambda}C_r(T - Tx)R_s$, with C_r = 0.025 and Tx = -3	C_r, T_x
Kimberley-Penman [22]	$PE = \frac{1}{\lambda\rho_w}\frac{\Delta(R_n - G) + K_u\gamma(a_w + b_w u_2)(e_s - e_a)}{\Delta+\gamma}$	/
	with $a_w = 0.4 + 1.4exp - \left[\left(\frac{J-173}{58}\right)^2\right]$	
	and $b_w = 0.605 + 0.345exp - \left[\left(\frac{J-243}{80}\right)^2\right]$	
Makkink [23]	$PE = a\frac{\Delta}{\Delta+\gamma}\frac{R_s}{\lambda} - b$, with a=0.61 and b=0.12	a, b
	or $PE = f * \frac{1}{\lambda\rho}\left(\frac{0.63R_s\Delta}{\Delta+\gamma} - 14\right)$	
Penman [24]	$PE = \frac{1}{\lambda\rho_w}\frac{\Delta(R_n - G) + K_u\gamma(a_w + b_w u_2)(e_s - e_a)}{\Delta+\gamma}$, with K_u = 6.43	a_w, b_w
Priestley-Taylor [25]	$PE = \frac{\alpha}{\lambda}\frac{\Delta}{\Delta+\gamma}R_n$, with α = 1.26	α
Penman-Monteith [27]	$PE = \frac{1}{\lambda}\left[\frac{\Delta(R_n - G) + K_m in \rho_a c_p(e_s - e_a)/r_a}{\left[\Delta + \gamma(1 + \frac{r_s}{r_a})\right]}\right]$, with k_{min}=86400	r_a, r_s
	with $r_a = \frac{ln\left[\frac{z_w - d}{z_{om}}\right] ln\left[\frac{z_h - d}{z_{oh}}\right]}{k^2 u_z}$ and $r_s = \frac{rl}{LAI_{active}}$	
Oudin [28]	$PE = \frac{R_e}{\lambda\rho}\frac{T_a + K_2}{K_1}$, if $T_a + K_2 > 0$, else $PE = 0$	K_1, K_2
	with K_1=100 and K_2=5	
Hamon [28]	$PE = \left(\frac{DL}{a}\right)^2 exp\left(\frac{T_a}{b}\right)$, with a=12 and b=16	a, b /

Penman

a_w and b_w are wind function coefficients that are usually receive a local or regional calibration. Penman

[26] used for clipped grass [27] a_w = 1.0 and b_w = 0.537.

"Jensen and Haise (1963) evaluated 3,000 observations of ET as determined by soil sampling procedures over a 35-year period. From about 100 values for well-watered crops with full cover in the western United States, a linear relationship of a solar radiation coefficient and mean air temperature was apparent. From these data, the constants for the following linear equation were CT=0.025 and Tx=-3 for temperature in C. Rs has the same units as λ ETr."

, where K_min units conversion, equal to 86,400 s d-1 for ET in mm d-1 and equal to 3600 s h-1 for ET in mm h-1. where zw = 2, zh = 2, d = 0.67 * h, zom = 0.123*h, zoh = 0.0123*h, k=0.41, u=wind, h=vegetation height

where rl = bulk stomatal resistance of a well-illuminated leaf 100sm-1, and LAI_{active}=0.5 LAI. rs=1/gs

FAO-reference + crop coefficient

3. Evaluation of PET models with original constant values

Priestley-Taylor
Makkink
Blaney-Criddle
Hargreaves
FAO-pm-reference
Kimberley-Penman
Jensen-Haise
Penman-Monteith
Penman
Oudin
Hamon
FAO-pm-reference + crop coefficient

4. Evaluation of PET models with calibrated constant values

Priestley-Taylor
Makkink
Blaney-Criddle
Hargreaves
Kimberley-Penman=Penman
Jensen-Haise
Penman-Monteith
Oudin
Hamon

Own plot
FAO-pm-reference + crop coefficient

5. Evaluation of PET models with calibrated constant values

Priestley-Taylor
α

6. Evaluation of PET models with original constant values/results

7. Evaluation of PET models with calibrated constant values/results

7.0.1. Inputs

R_n net longwave radiation BOKU station/ZAMG station

BOKU station bad data from 2017- ZMG.NAN values = (2015-09-25 - interpolate), (2017-09-20 - interpolate), (2018-03-16 till 2018-03-21 - drop?)
compare years 2015, 2016
R_n net longwave radiation BOKU station/ZAMG station

BOKU station bad data from 2017- ZMG.NAN values = (2015-09-25 - interpolate), (2017-09-20 - interpolate), (2018-03-16 till 2018-03-21 - drop?)
compare years 2015, 2016

$$R_n l = f_{cd}(a_1 + b_1\sqrt{e_a})\sigma T^4 \tag{2}$$

if 24-hour or longer time steps...T^4 transforms to $(T_{max}^4 - T_{min}^4)/2$.
σ is for daily values 4.901 x 10^{-9} MJm^{-2}d^{-1}K^{-4} with Rnl in MJm^{-2}d^{-1}
for hourly calculations σ = 2.042 x 10^{-10} MJm2 h^{-1}K^{-4}, Rnl is in MJm^{-2} h^{-1}.
Vegetation date of cuts:
GS-1=GS-2=GS-3=GS-4=GS-5=GS-6
(["2015-05-27","2015-07-28","2015-10-13"], ["2016-05-31","2016-07-26","2016-10-04"], ["2017-05-30","2017-07-25","2017-10-03"], ["2018-05-29","2018-07-24","2018-10-02"])

$$R_n l = f_{cd}(a_1 + b_1\sqrt{e_a})\sigma T^4 \tag{3}$$

if 24-hour or longer time steps...T^4 transforms to $(T_{max}^4 - T_{min}^4)/2$.
σ is for daily values 4.901 x 10^{-9} MJm^{-2}d^{-1}K^{-4} with Rnl in MJm^{-2}d^{-1}
for hourly calculations σ = 2.042 x 10^{-10} MJm2 h^{-1}K^{-4}, Rnl is in MJm^{-2} h^{-1}.
Wright and Jensen [22] developed an expression for f_{cd}:

$$f_{cd} = a\frac{R_S}{R_{SO}} + b \tag{4}$$

a and b are empirical coefficients. General a= 1.3, b=0.3, a_1 = 0.39 and b_1=0.158
Bulleted lists look like this:

- First bullet
- Second bullet
- Third bullet

Numbered lists can be added as follows:

1. First item
2. Second item
3. Third item

The text continues here.

7.1. Figures, Tables and Schemes

All figures and tables should be cited in the main text as Figure 1, Table 1, etc.

Figure 1. This is a figure, Schemes follow the same formatting. If there are multiple panels, they should be listed as: (**a**) Description of what is contained in the first panel. (**b**) Description of what is contained in the second panel. Figures should be placed in the main text near to the first time they are cited. A caption on a single line should be centered.

Text
Text

Table 2. This is a table caption. Tables should be placed in the main text near to the first time they are cited.

Title 1	**Title 2**	**Title 3**
entry 1	data	data
entry 2	data	data

Text
Text

7.2. Formatting of Mathematical Components

This is an example of an equation:

$$a + b = c \tag{5}$$

Please punctuate equations as regular text. Theorem-type environments (including propositions, lemmas, corollaries etc.) can be formatted as follows:

Theorem 1. *Example text of a theorem.*

The text continues here. Proofs must be formatted as follows:

Proof of Theorem 1. Text of the proof. Note that the phrase 'of Theorem 1' is optional if it is clear which theorem is being referred to. □

The text continues here.

8. Discussion

Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

9. Materials and Methods

Materials and Methods should be described with sufficient details to allow others to replicate and build on published results. Please note that publication of your manuscript implicates that you must make all materials, data, computer code, and protocols associated with the publication available to readers. Please disclose at the submission stage any restrictions on the availability of materials or information. New methods and protocols should be described in detail while well-established methods can be briefly described and appropriately cited.

Research manuscripts reporting large datasets that are deposited in a publicly available database should specify where the data have been deposited and provide the relevant accession numbers. If the accession numbers have not yet been obtained at the time of submission, please state that they will be provided during review. They must be provided prior to publication.

Interventionary studies involving animals or humans, and other studies require ethical approval must list the authority that provided approval and the corresponding ethical approval code.

10. Conclusions

This section is not mandatory, but can be added to the manuscript if the discussion is unusually long or complex.

11. Patents

This section is not mandatory, but may be added if there are patents resulting from the work reported in this manuscript.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "conceptualization, X.X. and Y.Y.; methodology, X.X.; software, X.X.; validation, X.X., Y.Y. and Z.Z.; formal analysis, X.X.; investigation, X.X.; resources, X.X.; data curation, X.X.; writing–original draft preparation, X.X.; writing–review and editing, X.X.; visualization, X.X.; supervision, X.X.; project administration, X.X.; funding acquisition, Y.Y.", please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

Funding: Please add: "This research received no external funding" or "This research was funded by NAME OF FUNDER grant number XXX." and and "The APC was funded by XXX". Check carefully that the details given are accurate and use the standard spelling of funding agency names at https://search.crossref.org/funding, any errors may affect your future funding.

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Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
TLA	Three letter acronym
LD	linear dichroism

Appendix A

Appendix A.1

The appendix is an optional section that can contain details and data supplemental to the main text. For example, explanations of experimental details that would disrupt the flow of the main text, but nonetheless remain crucial to understanding and reproducing the research shown; figures of replicates for experiments of which representative data is shown in the main text can be added here if brief, or as Supplementary data. Mathematical proofs of results not central to the paper can be added as an appendix.

Appendix B

All appendix sections must be cited in the main text. In the appendixes, Figures, Tables, etc. should be labeled starting with 'A', e.g., Figure A1, Figure A2, etc.

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