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Use of gridded data for the evaluation of ten radiation-based potential evapotranspiration models in a forest ecosystem in Greece

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Introduction

Accurate estimation of potential evapotranspiration (PET) is crucial in forest hydrology, as it is an important input parameter for forest stand and watershed hydrological models. However, obtaining the necessary input parameters for PET estimation especially in forests can be very difficult and expensive. Recent studies have used high-resolution gridded meteorological datasets with different spatial and temporal resolutions (Hassan et al. 2020), produced by applying various interpolation methods to the records of nearby agro-hydro-meteorological stations (Crespi et al. 2021), to estimate PET. The accuracy and the quality of these datasets depend on the data assimilation system and the methodology followed for the homogenization of the time series.

This work aims to investigate the uncertainties introduced in the estimation of daily PET when using the AGRI4CAST gridded interpolated dataset, in the environment of a Mediterranean forest as well as to evaluate the performance of 10 widely used radiation-based PET estimation models.

Materials and methods

The study focuses on an evergreen broadleaved forest stand in Western Greece (latitude 38°50′46′′, longitude 21°18′18′′, 340 m a.s.l). An automatic meteorological station (AMS) located 420 m away from the forest stand was used to measure various variables, on an hourly time-step for a period of 23 years (1996-2018). These variables include minimum, maximum, mean air temperature (°C), relative humidity (%), global solar radiation (W/m^2) and wind speed (m/s). Precipitation was measured using four rain gauges. To estimate daily reference evapotranspiration (PM_{ground}), a ground dataset containing 7,554 daily values was used covering 90% of the time period from 1996 to 2018. In addition, the gridded dataset AGRI4CAST "Gridded Agro-Meteorological Data in Europe" – node 51149 (Toreti 2014), which provides daily meteorological data for the period 1979-2020, was also employed to estimate PET (PM_{grid}). The PM_{grid} estimates from FAO56 Penman-Monteith and 10 other radiation-based methods were compared against the FAO56 Penman-Monteith method using ground data (PM_{ground}), for the common period 1996-2018. The performance of all models was evaluated by several statistical indices: coefficient of determination (R^2), intercept (a) and slope (b) of the linear regression factors of the least squared regression analysis, mean bias error (MBE), mean absolute error (MAE), weighted determination coefficient (wR^2), model efficiency (EF) and long-term average ratio (rt) (Bourletsikas et al. 2018).

Results and concluding remarks

The daily results of PM_{grid} were generally satisfactory, although an underestimation of 7.8% is observed in its mean value (Table 1). On the other hand, the radiation-based methods showed highly variable results. PM_{ABT}, PM_{HAM}, PM_{MAK} and $PM_{P\text{-}T}$ return underestimated mean PET values of 8.9%, 24.5%, 16.1% and 0.7% respectively, whereas PM_{CAP}, PM_{DeB}, PM_{F24}, PM_{HAN}, $PM_{J\text{-}H}$ and PM_{MCB} showed overestimated mean values of 30.0%, 1.0%, 15.7%, 0.4%, 16.3%, 18.2% respectively. The best MBE (0.013 mm) and rt (1.004) were displayed by PM_{HAN}, while PM_{ABT} returned the best intercept coefficient, wR^2 and EF indices. Overall, $PM_{P\text{-}T}$ had the best performance comparing all the examined statistical parameters. Compared with the results of Bourletsikas et al. (2018) results, an increase in mean R^2 of 3.0% (range 2.4%-4.4%) and a mean decrease in rt of 12% (3.1%-16.5%) were observed for all models. These results indicate the necessity of a cross-calibration analysis on the gridded data, mainly by the administrators of the data products which will result in an improvement to the three-dimensional regression model techniques (Thornton 2021) or by the user, carrying out a comparative analysis with the ground data (Ramirez-Cuesta 2017).

Table 1. Statistical analysis using gridded agrometeorological data for the estimation of daily PET (PMgrid) and 10 radiation-based methods against the PMground model during the study period (1996–2018, n=7554).

Method	a	b	R^2	MV	SD	rt	MBE	MAE	wR^2	EF
PM_{ground} Penman Monteith				3.34	2.20					
PM_{grid} Penman Monteith	1.1270	0.1314	0.918	3.08	1.87	0.922	-0.260	0.549	0.747	0.892
ET_{ABT} Abtew	0.9559	0.4317	0.922	3.04	2.20	0.911	-0.297	0.521	0.889	0.902
ET_{CAP} Caprio	0.7057	0.2759	0.882	4.34	2.92	1.300	1.002	1.177	0.706	0.521
ET_{DeB} DeBruin	0.9234	0.2237	0.878	3.37	2.23	1.010	0.035	0.601	0.834	0.871
ET_{F24} FAO24	0.8318	0.1242	0.919	3.86	2.53	1.157	0.531	0.712	0.832	0.825
ET_{HAM} Hamon	1.6328	0.7766	0.821	2.52	1.22	0.755	-0.818	1.148	0.413	0.559
ET_{HAN} Hansen	1.0739	0.2606	0.901	3.35	1.94	1.004	0.013	0.537	0.756	0.897
ET_{J-H} Jense-Haise	0.7576	0.3962	0.914	3.88	2.77	1.163	0.545	0.811	0.758	0.759
ET_{MAK} Makkink	1.2324	0.1131	0.901	2.80	1.69	0.839	-0.538	0.699	0.659	0.809
ET_{MGB} MacGuiness-Bordne	0.9204	0.2941	0.840	3.95	2.19	1.182	0.608	0.824	0.766	0.757
ET_{P-T} Priestley-Taylor	0.9241	0.2759	0.882	3.31	2.23	0.993	-0.024	0.588	0.842	0.876

In summary, point application of gridded datasets for the estimation of daily PET is very useful but the selection of the dataset is very important because of the cumulative error of the different variables used in complicated equations. These findings can be valuable to other experts in hydrological and climate research.

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