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A Thorough Evaluation of 127 Potential Evapotranspiration Models in Two Mediterranean Urban Green Sites

Nikolaos Proutsos [1,*], Dimitris Tigkas [2], Irida Tsevreni [3], Stavros G. Alexandris [4], Alexandra D. Solomou [1], Athanassios Bourletsikas [1], Stefanos Stefanidis [5] and Samuel Chukwujindu Nwokolo [6]

[1] Institute of Mediterranean Forest Ecosystems-Hellenic Agricultural Organization "DEMETER", Terma Alkmanos, 11528 Athens, Greece; asolomou@elgo.gr (A.D.S.); abourletsikas@elgo.gr (A.B.)
[2] Centre for the Assessment of Natural Hazards and Proactive Planning & Laboratory of Reclamation Works and Water Resources Management, National Technical University of Athens, 15780 Athens, Greece; ditigas@mail.ntua.gr
[3] Department of Early Childhood Education, University of Thessaly, 38221 Volos, Greece; itsevreni@uth.gr
[4] Department of Natural Resources Development and Agricultural Engineering, Agricultural University of Athens, 11855 Athens, Greece; stalex@aua.gr
[5] Laboratory of Mountainous Water Management and Control, School of Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece; stefstefanid@auth.gr
[6] Department of Physics, Faculty of Physical Sciences, University of Calabar, Calabar 540004, Nigeria; nwokolosc@unical.edu.ng
* Correspondence: np@fria.gr

Abstract: Potential evapotranspiration (PET) is a particularly important parameter for understanding water interactions and balance in ecosystems, while it is also crucial for assessing vegetation water requirements. The accurate estimation of PET is typically data demanding, while specific climatic, geographical and local factors may further complicate this task. Especially in city environments, where built-up structures may highly influence the micrometeorological conditions and urban green sites may occupy limited spaces, the selection of proper PET estimation approaches is critical, considering also data availability issues. In this study, a wide variety of empirical PET methods were evaluated against the FAO56 Penman–Monteith benchmark method in the environment of two Mediterranean urban green sites in Greece, aiming to investigate their accuracy and suitability under specific local conditions. The methods under evaluation cover all the range of empirical PET estimations: namely, mass transfer-based, temperature-based, radiation-based, and combination approaches, including 112 methods. Furthermore, 15 locally calibrated and adjusted models have been developed based on the general forms of the mass transfer, temperature, and radiation equations, improving the performance of the original models for local application. Among the 127 (112 original and 15 adjusted) evaluated methods, the radiation-based methods and adjusted models performed overall better than the temperature-based and the mass transfer methods, whereas the data-demanding combination methods received the highest ranking scores. The adjusted models seem to give accurate PET estimates for local use, while they might be applied in sites with similar conditions after proper validation.

Keywords: micrometeorology; evapotranspiration; Mediterranean conditions; urban green; vegetation water requirements

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1. Introduction

Evapotranspiration (ET) is a key component of the water cycle, while in rainfed ecosystems, it is the main consumer of available precipitation water [1–3]. The anticipated climate trends suggest that the magnitude of ET will increase due to warming and changing precipitation patterns impacting the earth's ecosystems [4]. Due to its significance, accurate measurements or estimates of ET are crucial. However, direct ET measurement by methods such as lysimeters [5] or eddy covariance [6,7] is difficult to obtain due to the high requirements of expensive equipment or application difficulties. The estimation of ET by common meteorological data is generally acceptable, since it is easier and in many cases produces reliable estimates.

The site-specific characteristics highly influence the ET magnitudes. Thus, numerous estimation models have been proposed worldwide with different approaches, whereas the substrate at each site highly influences the ET rates [8]. In general, four major groups of methods can be defined to classify the empirical ET models: the mass-transfer-based methods, the temperature-based methods, the radiation-based methods and the combination methods. In all cases, the proposed equations aim to provide reliable estimates of the water demand driven by atmospheric conditions by minimizing the impact of plant species, vegetation stage or soil. To accomplish this, the estimates of ET are generally mentioned as potential (PET) or reference evapotranspiration, which are two different terms for expressing the water demand with different conceptual physical bases. The selection of the appropriate PET method is particularly important as it affects hydrometeorological and climatic variables that are linked to the sustainability of natural ecosystems [9].

Raza et al. [10] performed a comprehensive review on studies using several empirical evapotranspiration models and found that Thornthwaites' 1948 and Hargreaves–Samani's 1985 models were the most widely used among the temperature-based models, whereas Priestley 1972 and Ritchie 1972 were also the most often used among the radiation-based ones. However, the Penman–Monteith model is the most widely used in all categories.

The Penman–Monteith model is generally accepted as the most accurate method to estimate maximum ET as also suggested by the FAO (Food and Agriculture Organization of the United Nations) and WMO (World Meteorological Organization). In many studies, FAO56-PM is used as the standard method to compare and evaluate the performance of other methods in specific sites, areas or regions [11–17]. The FAO adopted the concept of reference evapotranspiration in the FAO guidelines for crop water requirements by Doorenbos and Pruitt [18,19]. This approach to calculating crop evapotranspiration is widely accepted by engineers, agronomists and researchers in practice, design and research. The reference concept relates to a growing reference grass crop and is represented in FAO-24 by climate types calibrated with lysimeter data from various locations [20]. However, many have pointed to weaknesses in the FAO-24 methodologies for implementation on a global scale. Researchers have tried to improve the evapotranspiration estimations for different locations and data availability through experimental and theoretical studies. First, the correlation of the calculated crop evapotranspiration with a reference crop proved difficult. The definition of a grass variety and its morphological characteristics have not been standardized for different climatic conditions. Furthermore, grass management varies from site to site and over time within the same site. Others have suggested alfalfa as a reference crop, but they have encountered similar variety and management problems [11,21–24].

The FAO 56 Penman–Monteith equation incorporating standardized roughness and the bulk surface resistance parameters is recommended as the globally used equation to represent the new definition of reference evapotranspiration, replacing the Penman combination model. Thus, the reference grass evapotranspiration is redefined as the evapotranspiration from a clipped extended grass surface of 12 cm height with a total surface resistance equal to 70 s m^{-1}. This change in definition and the choice of a specific calculation method is intended to help eliminate problems in measuring a true evapotranspiration rate and provide consistent estimates across regions of the globe. The use of the FAO Penman–Monteith equation overcomes the overestimation problems of the earlier FAO Penman combination method. A hypothetical calculation of reference evapotranspiration can be used to calibrate empirical evapotranspiration equations and be considered as the basis for determining crop coefficients where evapotranspiration cannot be measured simultaneously with specific crop evapotranspiration.

The need for new methods is generally imposed, because FAO56-PM produces accurate PET estimates, but for its application, a considerable number of meteorological parameters is required, which in many areas are not measured. Thus, the adjustment or calibration of simpler original method with fewer data requirements is very important to accurately estimate PET, particularly in regions where meteorological data are rare.

Solar radiation and air temperature are related parameters, considered as the most important for the determination of PET especially in summer [25,26], whereas relative humidity typically drives ET in winter [25]. The impact of wind speed appears to be minor [25]; however, there are studies [27] indicating a strong wind dependence of PET. In all cases, the large spatial variability and the site-specific characteristics are considered as key factors for the formation of PET [27,28] along with seasonality [25,26].

Several methods have been proposed for PET estimation. The method of Hargreaves and Samani (1985) was extensively used in many applications due to the low data requirements as well as its simplicity in application. Similar approaches were proposed by many authors including Schendel [29], Baier-Robertson [30], and Trajkovic [31]. Shirmohammadi-Aliakbarkhani and Saberali [32] suggested that the Hargreaves–Samani method is a simple and reliable alternative for the estimation of ET in arid areas of Iran by assessing meteorological data from 13 sites in northeast Iran. The methods of Thornthwaite, Priestley and Taylor, Makkink and Abtew are recommended for humid climates, while this of Hargreaves and Samani is recommended for arid and semi-arid conditions, and those of Hamon and Linacre are recommended for all climates.

In general, simple empirical equations were evaluated for a variety of climates and regions worldwide, presenting different performances and imposing also the need for local calibration. Lang et al. [16] investigated the performance of eight methods in southwestern China and found high variability between different regions. The authors found that Hargreaves–Samani, Priestley-Taylor and Abtew were overestimating and Makkink, Thornthwaite, Hammon, Linacre and Blaney-Criddle were underestimating ET, although they addressed the good performance of specific methods when applied to specific regions of southwestern China. Lang et al. [16] also supported the overall better performance of the radiation-based methods compared to the temperature-based ones, proposing Makkink as the best radiation method and Hargreaves–Samani as the best temperature method for their study area.

Similarly, Makkink was reported to perform well in Malaysia [33], but its performance was poor in the southeastern United States [34], and this was attributed to the different climatic conditions and geographical environments [16]. Priestley-Taylor was suggested by Wei and Menzel [35] as the most suitable method for global application. Thornthwaite was found to perform worst in many regions [16,34,36,37], which was probably because it takes into consideration only temperature and because it was established in a valley's humid climate. There are, however, many studies suggesting Thornthwaite as a well-performing method, e.g., in Malaysia [38,39].

Bourletsikas et al. [14] evaluated the performance of 24 empirical PET models in a forest ecosystem in central Greece, using daily data for a 17-year time period and several statistical indices. They suggested the use of Copais and original Hargreaves methods for the daily PET estimation in forest environments, which were followed by Valiantzas (T, Rs) and Valiantzas (T, Rs, RH). The authors also proposed using the models of Turc, modified Hargreaves–Samani after Droogers and Allen (2002), the Sun Thermal Unit (STU), and Jensen-Haize, which also had a good performance. They also recommended local calibration for the use of all tested mass transfer-based methods (Albrecht, Mahringer, Penman, Romanenco, WMO), as well as Abtew, Caprio, de Bruin-Keijman, FAO24 Radiation, Hansen, Makkink, McGuiness-Brondne, Priestley-Taylor and modified Thornthwaite by Siegert and Schrodter.

In all cases, the characteristics of the surfaces, the prevailing local conditions and the number of input parameters in the empirical models affect the accuracy of the PET estimates. Bogawski and Bednorz [40] reported on the decreasing performance of PET empirical methods with data availability.

Assessments of PET are typically performed in agricultural areas or on the larger scale of a basin. In the urban environment, PET is generally neglected, since the built-up cities covered by a variety of materials prevent the free movement of water or make it difficult to be studied. However, in urban green areas (i.e., parks), PET is of critical importance, determining the water requirements of the urban vegetation for its survival in the city's unfavorable environment, which are characterized by increased temperatures and thermal stress as well as reduced water vapor content and decreased water quantities for irrigation, especially in Mediterranean and arid climates. In a recent study by Zhou et al. [41], the authors describe the complex heat storage and shading effects in the urban environment, underlining also that only neglecting the shading effects leads to an overestimation of urban evapotranspiration of about 38.7%. In addition, the variable reflectance characteristics of the urban surfaces (even green ones) and surface temperatures in association with urban heat island and drought phenomena are highly affecting ET [42–44] in the cities.

The aim of this study is to extend the existing knowledge and understanding about the impact of the built-up environment on the water requirements of urban vegetation, considering the significance of urban green spaces and their multiple socioeconomic and environmental benefits [45,46]. Toward this goal, 112 empirical PET methods were thoroughly evaluated against the benchmark FAO56-PM method in the Mediterranean environment of two Greek cities. Specifically, high-quality data from meteorological stations located above two urban green sites were used to test the performance of the methods including temperature-based, radiation-based, mass transfer and combination approaches, distinguishing the most suitable ones under different conditions and data availability schemes. In addition, locally adjusted mass transfer, temperature and radiation-based models are developed for enhancing the accuracy of PET estimations while maintaining low data requirements. Apart from the evaluation of a significantly high number of methods which have been rarely used in the literature, this study focuses on the research of micrometeorological aspects of urban green areas, which can provide crucial information for this vital resource for sustainable and quality life in the city under a changing climate.

2. Materials and Methods

2.1. Study Sites and Instrumentation

The present study was conducted in urban green areas in two cities in Greece: Amaroussion (central Greece) and Heraklion (South Greece-Crete island). The sites' locations are presented in Figure 1.

The study site in Amaroussion (38.04°N, 23.80°E, alt.: 190 m a.s.l.) is in an urban green space with an area of 9.1 ha covered with a variety of plant species including grass, shrubs (e.g., *Lavandula angustifolia* Mill., *Nerium oleander* L., *Rosmarinus officinalis* L., *Teucrium fruticans* L.), herbaceous species (e.g., *Calendula arvensis* (Vaill.) L., *Capsella bursa-pastoris* (L.) Medik., *Convolvulus arvensis* L., *Lactuca serriola* L., *Matricaria recutita* L., *Pallenis spinosa* (L.) Cass., *Plantago lanceolata* L., *Solanum elaeagnifolium* Cav.), and generally deciduous broad-leaved tree species (e.g., *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Cercis siliquastrum* L., *Melia azedarach* L., *Morus alba* L., *Platanus orientalis* L., *Prunus cerasifera* Ehrh., *Tilia tomentosa* Moench), in mixed patterns. The climate of the broader area is characterized as semi-arid [47–49], according to UNEP's [50] aridity climate classification system based on Thornthwaite's [51,52] water balance approach. A detailed description of the study site can be also found in Proutsos et al. [43] and in Solomou et al. [53].

The site in Heraklion (35.31°N, 25.14°E, alt.: 81 m a.s.l.) is located in the island of Crete in the southern part of Europe. It is also an urban green area covered to a lesser degree by vegetation. The vegetation in the site includes trees, shrubs and herbaceous plants. The trees are generally deciduous broad-leaved (e.g., *Ficus carica* L., *F. elastica* Roxb., *Citrus reticulata* L., *C. limon* L., *Olea europaea* L., *Pinus brutia* Tenore.) and randomly distributed in the site. The shrub-covered surfaces host a variety of species (e.g., *Pittosporum tobira* (Thunb.) W.T. Aiton, *Nerium oleander* L., *Rosmarinus officinalis* L.) in mixed patterns with herbaceous plants (e.g., *Convolvulus arvensis* L., *Glebionis coronaria* (L.) Spach, *Malva sylvestris*

L., *Medicago lupulina* L., *Oxalis pescaprae* L.). The climate in the area is sub-humid [48,49] according UNEP's [50] aridity classification system based on Thornthwaite's [51,52] water balance approach, presenting also high decadal variability to warmer [54,55], more arid conditions [49,56] with more frequent droughts in the recent years compared to the past [55].

Figure 1. (**a**) Map of the sites and (**b**) photos of the meteorological stations installed in the urban green spaces (UGSs) of (**a**) Heraklion (S. Greece—Crete island), and (**c**) Amaroussion (central Greece).

In the two sites, two micrometeorological stations were established for the constant monitoring of the aerial and soil environment. Both stations were equipped with sensors measuring temperature-relative humidity (EE08, E+E Elektronik Ges.m.b.H., Engerwitzdorf, Austria), wind speed and wind direction (Small Wind Transmitter, THIES CLIMA, Adolf Thies GmbH & Co. KG, Göttingen, Germany), precipitation (PROFESSIONAL, Pronamic ApS, Skjern, Denmark), global solar radiation at wavelengths 305–2800 nm (Pyranometer SP-Lite, ADCON Telemetry, Klosterneuburg, Austria, with a sensitivity change of 2% per year), and photosynthetically active radiation at 400–700 nm (QSO-S Quantum sensor, Apogee Instruments, Inc., Logan, Utah, USA, with ±5% accuracy). The measurements were conducted every 5 s, and the 10 min averages were recorded.

The available data cover the time period from 24 September 2019 to 31 December 2022 in Amaroussion and from 18 October 2019 to 31 December 2022 in Heraklion. During these periods, the monthly values of temperature, relative humidity, wind speed and precipitation in the two sites are presented in Figure 2. The acquired data patterns are rather expected for the climatic patterns of these areas.

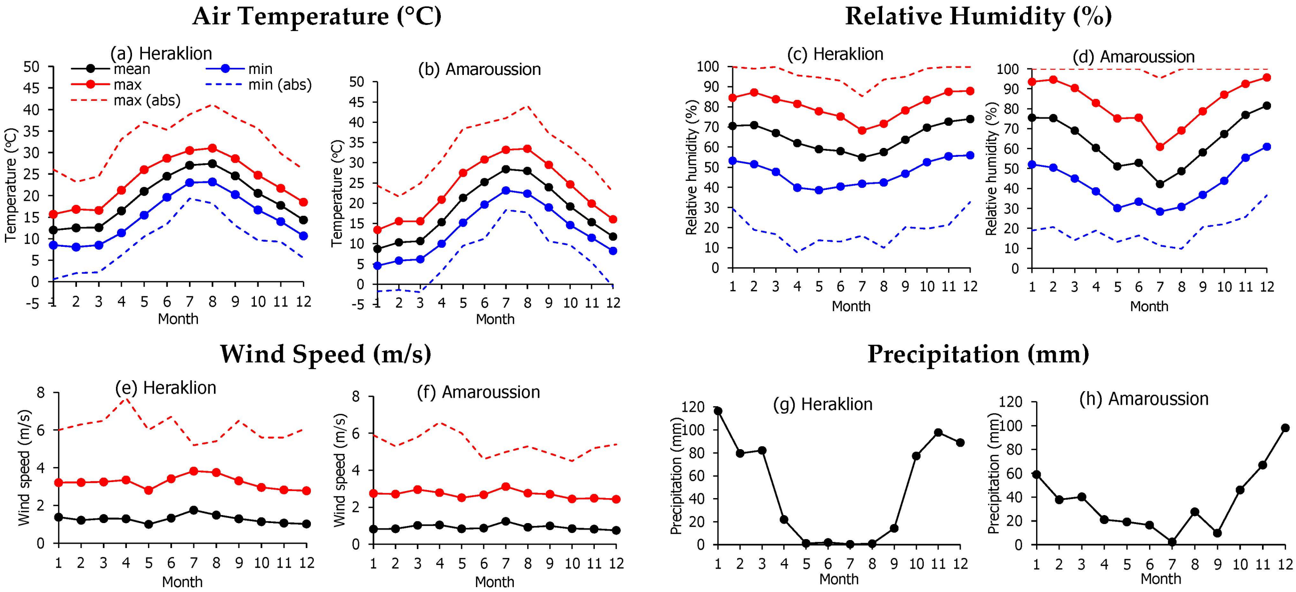

Figure 2. Monthly average, minimum and maximum values of (**a**) air temperature in Heraklion, (**b**) air temperature in Amaroussion, (**c**) relative humidity in Heraklion, (**d**) relative humidity in Amaroussion, (**e**) wind speed and gust in Heraklion, (**f**) wind speed and gust in Amaroussion, (**g**) precipitation in Heraklion and (**h**) precipitation in Amaroussion.

2.2. PET Methods

The estimation of PET was performed by employing 112 empirical methods, which can be categorized into four distinct groups based on their required variables for their application:

- 12 mass-transfer-based methods following the general form of PET = f (u, T, RH). These methods are based on the assumption that evapotranspiration is affected by the air movements considering also atmospheric dryness, which is expressed by the difference between air vapor pressure at saturation (e_s) and actual vapor pressure (e_a). In all cases, the vapor pressure deficit effect is corrected by the addition of the aerodynamic term as a function of wind speed u. For the PET estimation, wind speed (u), air temperature (T) and relative humidity (RH) data are required. The analytical expressions of the 12 mass transfer empirical equations (Equations (1)–(12) used in this work are presented in Table 1.
- 48 temperature-based methods following the general forms of PET = f (T), 34 methods (Equations (13)–(46)); PET = f (T, RH), 13 methods (Equations (47)–(59)); and PET = f (T, PR), 1 method (Equation (60)), presented in Table 2.

- 40 radiation-based methods following the general forms of PET = f (Rs), 2 methods (Equations (61) and (62)); PET = f (Rs, T), 21 methods (Equations (63)–(83)); and PET = f (Rs, T, RH), 17 methods (Equations (84)–(100)), presented in Table 3.
- 13 combination methods following the general forms of PET = f (Rs, u, T, RH), 12 methods, (Equations (101)–(111) and the benchmark method FAO56-PM [11]); and PET = f (Rs, u, T), 1 method (Equation (112)), presented in Table 4.

Table 1. Mass transfer-based methods. General form PET = f (u, T, RH).

Mass Transfer Methods	Equation PET = f (u, T, RH) *	Equation	Ref.
Dalton 1802	$PET = (3.648 + 0.7223u)(e_s - e_a)$	(1)	[57]
Fitzgerald 1886	$PET = (4 + 1.99\,u)(e_s - e_a)$	(2)	[58]
Trabert 1896	$PET = 3.075\,\sqrt{u}\,(e_s - e_a)$	(3)	[59]
Meyer 1926	$PET = (3.75 + 0.5026u)(e_s - e_a)$	(4)	[60]
Rohwer 1931	$PET = (3.3 + 0.891u)(e_s - e_a)$	(5)	[61]
Penman 1948	$PET = (2.625 + 1.3812\,u)\,(e_s - e_a)$	(6)	[62]
Albrecht 1950	$PET = \begin{cases} (1.005 + 2.97\,u)\,(e_s - e_a), & \text{for } u \leq 1\ m/s \\ 4\,(e_s - e_a), & \text{for } u > 1\ m/s \end{cases}$	(7)	[63,64]
Brock. and Wenner 1963	$PET = 5.43\,u^{0.456}\,(e_s - e_a)$	(8)	[65]
WMO 1966	$PET = (1.298 + 0.934\,u)\,(e_s - e_a)$	(9)	[66]
Mahringer 1970	$PET = 2.86\,\sqrt{u}\,(e_s - e_a)$	(10)	[67]
Szász 1973	$PET = 0.00536\,(T + 21)^2\,\left(1 + \frac{RH}{100}\right)^{2/3}(0.0519\,u + 0.905)$	(11)	[68]
Linacre 1992	$PET = (0.015 + 0.0004\,T + 0.000001\,z)\left[\frac{380\,(T+0.006\,z)}{84-\varphi} - 40 + 4u\,(T - T_d)\right]$	(12)	[69]

* where u is the wind speed at 2 m height in m s^{-1}, T is the air temperature in °C, T_d is the dew-point in °C, RH is the relative humidity in %, e_s and e_a are the saturation and actual vapor pressures, respectively, in kPa, z is the altitude and φ is the geographical latitude in degrees.

Table 2. Temperature-based methods. General forms PET = f (T), PET = f (T, RH) and PET = f (T, PR).

Temperature-Based Methods	Equation PET = f (T) *	Equation	Ref.
Thornthwaite 1948	$PET = 16\left(\frac{10\,T}{I}\right)^a \frac{N}{360},\ I = \sum_1^{12}(0.2\,T)^{1.514}$	(13)	[51,70]
Blaney and Criddle 1950	$PET = \begin{cases} 0.85\,p\,(0.46\,T + 8.13), & \text{from April to September} \\ 0.45\,p\,(0.46\,T + 8.13), & \text{from October to March} \end{cases}$	(14)	[71]
McCloud 1955	$PET = 0.254 \cdot 1.07^{1.8\,T}$	(15)	[72]
Hamon 1963	$PET = 29.8\,N\left(\frac{e_s}{T + 273.2}\right)$, for T > 0	(16)	[73,74]
Baier and Robertson 1965	$PET = 0.157\,T_{max} + 0.158\,(T_{max} - T_{min}) + 0.109\,R_a - 5.39$	(17)	[30]
Malmstrom 1969	$PET = 40.9\,e_s \frac{N}{360}$	(18)	[73]
Siegert and Schrodter 1975	$PET = 0.533\left(\frac{10\,T}{33.617}\right)^{1.033} \frac{N}{12}$	(19)	[75]
Blaney and Criddle (Mid.Eu,. ver.)	$PET = -1.55 + 0.96\,p\,(0.457\,T + 8.128)$	(20)	[19]
Smith and Stopp 1978	$PET = 0.16\,T$	(21)	[76]
Hargreaves and Samani 1985	$PET = 0.0023\,(T_{max} - T_{min})^{0.5}\,(T + 17.8)\,R_a$	(22)	[77]
Kharrufa 1985	$PET = 0.34\,p\,T^{1.3}$	(23)	[78]
Mintz and Walker 1993	$PET = 0.17 \frac{N}{12} T$	(24)	[79]
Camargo et al. 1999	$PET = 16\left(\frac{10\,T_{ef}}{I}\right)^a \frac{N}{360},\ I = \sum_1^{12}(0.2\,T_{ef})^{1.514},$ $T_{ef} = 0.36(3T_{max} - T_{min})$	(25)	[80]
Samani 2000	$PET = 0.0135\,KT\,R_a\,(T_{max} - T_{min})^{0.5}\,(T + 17.8)$ $KT = 0.00185\,(T_{max} - T_{min})^2 - 0.0433\,(T_{max} - T_{min}) + 0.4023$	(26)	[77,81,82]
Xu and Singh 2001 (1)	$PET = 20\left(\frac{10\,T}{I}\right)^a \frac{N}{360},\ I = \sum_1^{12}(0.2\,T)^{1.514}$	(27)	[83]
Xu and Singh 2001 (2)	$PET = 20.5\left(\frac{10\,T}{I}\right)^a \frac{N}{360},\ I = \sum_1^{12}(0.2\,T)^{1.514}$	(28)	[83]
Xu and Singh 2001 (3)	$PET = 0.37\,p\,T^{1.3}$	(29)	[83]

Table 2. *Cont.*

Temperature-Based Methods	Equation PET = f (T) *	Equation	Ref.
Xu and Singh 2001 (4)	$PET = 0.0028\ (T_{max} - T_{min})^{0.5}\ (T + 17.8)\ R_a$	(30)	[83]
Droogers and Allen 2002 (1)	$PET = 0.0030\ (T_{max} - T_{min})^{0.4}\ (T + 20)\ R_a$	(31)	[84]
Droogers and Allen 2002 (2)	$PET = 0.0025\ (T_{max} - T_{min})^{0.5}\ (T + 16.8)\ R_a$	(32)	[84]
Pereira and Pruitt 2004	$PET = 16\left(\frac{10\ T^*_{ef}}{I}\right)^a \frac{N}{360}, I = \sum_1^{12}(0.2\ T_{ef})^{1.514}$ $T^*_{ef} = 0.345(3T_{max} - T_{min})\frac{N}{24-N}$ for $T \le T^*_{ef} \le T_{max}$	(33)	[70]
Trajcovic 2005 (1)	$PET = 0.88\left[16\left(\frac{10\ T}{I}\right)^a \frac{N}{360}\right] + 0.565, I = \sum_1^{12}(0.2\ T)^{1.514}$	(34)	[85]
Trajcovic 2005 (2)	$PET = 0.817\left[0.0023\ (T_{max} - T_{min})^{0.5}\ (T + 17.8)\ R_a\right] + 0.320$	(35)	[85]
Oudin 2005	$PET = R_a \frac{T+5}{100}$, for $T + 5 > 0$	(36)	[86]
Castañeda and Rao 2005 (1)	$PET = \begin{cases} 0.9\ p\ (0.46\ T + 8.13), & \text{from April to September} \\ 0.6\ p\ (0.46\ T + 8.13), & \text{from October to March} \end{cases}$	(37)	[87]
Trajkovic 2007	$PET = 0.0023\ (T_{max} - T_{min})^{0.424}\ (T + 17.8)\ R_a$	(38)	[31]
Tabari and Talaee 2011 (1)	$PET = 0.0031\ (T_{max} - T_{min})^{0.5}\ (T + 17.8)\ R_a$	(39)	[88]
Tabari and Talaee 2011 (2)	$PET = 0.0028\ (T_{max} - T_{min})^{0.5}\ (T + 17.8)\ R_a$	(40)	[88]
Ravazzani et al. 2012	$PET = (0.817 + 0.00022z)\ 0.0023R_a\ (T + 17.8)(T_{max} - T_{min})^{0.5}$	(41)	[89]
Berti et al. 2014	$PET = 0.00193\ R_a\ (T + 17.8)(T_{max} - T_{min})^{0.517}$	(42)	[90]
Heydari and Heydari 2014	$PET = 0.0023\ (T_{max} - T_{min})^{0.611}\ (T + 9.519)\ R_a$	(43)	[91]
Dorji et al. 2016	$PET = 0.002\ (T_{max} - T_{min})^{0.296}\ (T + 33.9)\ R_a$	(44)	[92]
Lobit et al. 2018	$PET = 0.1555\ R_a(0.00428\ T + 0.09967)\ (T_{max} - T_{min})^{0.5}$	(45)	[93]
Althoff et al. 2019	$PET = 0.0135 \cdot 0.166\ R_a\ (T_{max} - T_{min})^{0.5}\ (T + 15.3)$	(46)	[94]
	Equation PET = f (T, RH) *		
Romanenko 1961	$PET = 0.0018\ (25 + T)^2\ (100 - RH)\frac{N}{360}$	(47)	[95]
Papadakis 1965	$PET = 2.5\ [e_{ma} - e_d]$	(48)	[96]
Schendel 1967	$PET = 16\ \frac{T}{RH}$	(49)	[29]
Antal 1968	$PET = 0.736\ (e_s - e_a)^{0.7}\left(1 + \frac{T}{273}\right)^{4.8}$	(50)	[97,98]
Linacre 1977	$PET = \left[\frac{500(T+0.006z)}{100-\varphi} + 15(T - T_d)\right]/(80 + T)$	(51)	[99]
Naumann 1987	$PET = 0.18\ N\ (e_s^{14} - e_a^{14})$	(52)	[100]
Xu and Singh 2001 (5)	$PET = 0.0020\ (25 + T)^2\ (100 - RH)\frac{N}{360}$	(53)	[83]
Xu and Singh 2001 (6)	$PET = \left[\frac{488(T+0.006z)}{100-\varphi} + 15(T - T_d)\right]/(80 + T)$	(54)	[83]
Xu and Singh 2001 (7)	$PET = \left[\frac{615(T+0.006z)}{100-\varphi} + 15(T - T_d)\right]/(80 + T)$	(55)	[83]
Ahooghalaandari et al. 2016 (1)	$PET = 0.252\ R_a + 0.221\ T\left(1 - \frac{RH}{100}\right)$	(56)	[101]
Ahooghalaandari et al. 2016 (2)	$PET = 0.29\ R_a + 0.15\ T_{max}\left(1 - \frac{RH}{100}\right)$	(57)	[101]
Ahooghalaandari et al. 2016 (3)	$PET = 0.369\ R_a + 0.139\ T_{max}\left(1 - \frac{RH}{100}\right) - 1.95$	(58)	[101]
Ahooghalaandari et al. 2016 (4)	$PET = 0.34\ R_a + 0.182\ T\left(1 - \frac{RH}{100}\right) - 1.55$	(59)	[101]
	Equation PET = f (T, PR) *		
Droogers and Allen 2002 (3)	$PET = 0.0013\ (T_{max} - T_{min} - 0.0123PR)^{0.76}\ (T + 17)\ R_a$	(60)	[84]

* where $a = 6.75 \times 10^{-7}\ I^3 - 7.71 \times 10^{-5}\ I^2 + 1.7912 \times 10^{-2}\ I + 0.49239$ (Equations (13), (25), (27), (28), (33) and (34)), p represents the daily percentage (%) of annual daytime hours for each day of the year, N represents the maximum sunshine daily hours, T, T_{max} and T_{min} are the daily mean, maximum and minimum air temperatures in °C, T_d is the dewpoint in °C, RH is the relative humidity in %, φ is the latitude in degrees, z is the altitude in m, PR is the monthly precipitation in mm, Ra is the extraterrestrial radiation in mm day^{-1} in all equations except those from Baier and Robertson 1965 (Equation (17)) and Lobit et al. 2018 (Equation (45)), where Ra is in MJ $m^{-2}\ d^{-1}$, e_s and e_a are the saturation and actual vapor pressures in kPa in all equations except those from Antal 1968 (Equation (50)), where they are in hPa, e_{ma} is the saturation vapor pressure at daily maximum temperature in kPa and $e_s{}^{14}$ and $e_a{}^{14}$ are the e_s and e_a values in kpa at 14 h local time.

Table 3. Radiation-based methods PET = f (Rs) and PET = f (Rs, T, RH).

Radiation-Based Methods	Equation PET = f (Rs) *	Equation	Ref.
Christiansen 1968	$PET = 0.385\,\frac{R_s}{\lambda}$	(61)	[102]
Abtew 1996 (1)	$PET = 0.52\frac{R_s}{\lambda}$	(62)	[103]
	Equation PET= f (Rs, T) *		
Makkink 1957	$PET = 0.61\,\frac{\Delta}{\Delta+\gamma}\,\frac{R_s}{\lambda} - 0.12$	(63)	[104]
Steph. and Stewart 1963	$PET = \left[0.0082\left(\frac{9}{5}\,T + 32\right) - 0.19\right]\,\frac{23.9\,R_s}{1500}25.4$	(64)	[105]
Jensen and Haise 1963	$PET = \frac{R_s}{\lambda}(0.025\,T + 0.08)$	(65)	[106]
Stephens 1965	$PET = (0.0158\,T - 0.09)\,R_s$	(66)	[107,108]
McGuin. and Bord. 1972	$PET = (0.0059685\,T + 0.02927624)\,R_s$	(67)	[109]
Ritchie 1972	$PET = a_1\,0.00387\,R_s\,(0.6\,T_{max} + 0.4\,T_{min} + 29)$, $a_1 = \begin{cases} 1.1,\ \text{for } 5\,^\circ C < T_{max} < 35\,^\circ C \\ 1.1 + 0.05(T_{max} - 35),\ \text{for } T_{max} > 35\,^\circ C \\ 0.1 + e^{0.18(T_{max}+20)},\ \text{for } 5 < T_{max} < 5\,^\circ C \end{cases}$	(68)	[110,111]
Caprio 1974	$PET = 6.1\,10^{-3}\,R_s\,(1.8\,T + 1)$	(69)	[112]
Hargreaves 1975	$PET = 0.0135\,\frac{R_s}{\lambda}(T + 17.8)$	(70)	[113]
Hansen 1984	$PET = 0.7\frac{\Delta}{\Delta+\gamma}\,\frac{R_s}{\lambda}$	(71)	[114]
de Bruin 1987	$PET = 0.65\frac{\Delta}{\Delta+\gamma}\,\frac{R_s}{\lambda}$	(72)	[115–117]
Wendl. 1991–1995	$PET = (100\,R_s + 93K)\frac{T+22}{150(T+123)}$	(73)	[118,119]
Abtew 1996 (2)	$PET = 0.012\,\frac{(23.89\,R_s+50)\,T_{max}}{T_{max}+15}$	(74)	[103]
Abtew 1996 (3)	$PET = \frac{1}{56}\,\frac{T_{max}\,R_s}{\lambda}$	(75)	[103]
Irmak et al. 2003 (1)	$PET = 0.149\,R_s + 0.079\,T - 0.611$	(76)	[120]
Irmak et al. 2003 (2)	$PET = 0.286\,R_s + 0.134\,T - 2.959$	(77)	[120]
Irmak et al. 2003 (3)	$PET = 0.264\,R_s - 0.052T_{max} + 0.233\,T_{min} - 1.110$	(78)	[120,121]
Castañeda and Rao 2005 (2)	$PET = 0.70\,\frac{\Delta}{\Delta+\gamma}\,\frac{R_s}{\lambda} - 0.12$	(79)	[87]
Valiantzas 2013 (1)	$PET = 0.0393\,R_s\,\sqrt{T + 9.5} - 0.19\,R_s^{0.6}\,\varphi^{0.15} + 0.0061\,(T + 20)\,(1.12\,T - T_{min} - 2)^{0.7}$	(80)	[122,123]
Tabari et al. 2013 (1)	$PET = -0.642 + 0.174\,R_s + 0.0353\,T$	(81)	[124]
Tabari et al. 2013 (2)	$PET = -0.478 + 0.156\,R_s - 0.0112\,T_{max} + 0.0733\,T_{min}$	(82)	[124]
Ahooghal. et al. 2017 (1)	$PET = 0.79{\cdot}0.0393\,R_s\,\sqrt{T + 9.5} - 0.94{\cdot}0.19\,R_s^{0.6}\,\varphi^{0.15} + 2.21{\cdot}0.0061\,(T + 20)\,(1.12\,T - T_{min} - 2)^{0.7}$	(83)	[125]
	Equation PET = f (Rs, T, RH) *		
Turc 1961	$PET = \begin{cases} 0.013\,(23.9\,R_s + 50)\frac{T}{T+15},\ \text{for RH} > 50 \\ 0.013\,(23.9\,R_s + 50)\frac{T}{T+15}\left(1 + \frac{50-RH}{70}\right),\ \text{for RH} \le 50 \end{cases}$	(84)	[126]
Priestley and Taylor 1972	$PET = 1.26\,\frac{\Delta}{\Delta+\gamma}\,\frac{R_n-G}{\lambda}$	(85)	[127]
Abtew 1996 (4)	$PET = 1.18\,\frac{\Delta}{\Delta+\gamma}\,\frac{R_n-G}{\lambda}$	(86)	[103,128]
Xu and Singh 2000	$PET = 0.98\,\frac{\Delta}{\Delta+\gamma}\,\frac{R_n-G}{\lambda} - 0.94$	(87)	[129]
Irmak et al. 2003 (4)	$PET = 0.289\,R_n + 0.023\,T + 0.489$	(88)	[120]
Irmak et al. 2003 (5)	$PET = 0.435\,R_n + 0.095\,T - 1.149$	(89)	[120]
Irmak et al. 2003 (6)	$PET = 0.432\,R_n + 0.043\,T_{max} + 0.055\,T_{min} - 1.077$	(90)	[120,121]
Bereng. and Gavil. 2005	$PET = 1.65\,\frac{\Delta}{\Delta+\gamma}\,\frac{R_n-G}{\lambda}$	(91)	[130]
Copais	$PET = m_1 + m_2\,C_2 + m_3\,C_1 + m_4\,C_1\,C_2$, where $m_1 = 0.057$, $m_2 = 0.277$, $m_3 = 0.643$, $m_4 = 0.0124$ $C_1 = 0.6416 - 0.00784\,RH + 0.372\,R_s - 0.00264\,R_s\,RH$ $C_2 = -0.0033 + 0.00812\,T + 0.101\,R_s + 0.00584\,R_s\,T$	(92)	[131]
Valiantzas 2006 (1)	$PET = 0.038\,R_s\,\sqrt{T + 9.5} - 2.4\left(\frac{R_s}{R_a}\right)^2 + 0.075\,(T + 20)\left(1 - \frac{RH}{100}\right)$	(93)	[132]
Tabari and Talaee 2011 (3)	$PET = 2.14\,\frac{\Delta}{\Delta+\gamma}\,\frac{R_n-G}{\lambda}$	(94)	[88]
Tabari and Talaee 2011 (4)	$PET = 1.82\,\frac{\Delta}{\Delta+\gamma}\,\frac{R_n-G}{\lambda}$	(95)	[88]
Valiantzas 2013 (2)	$PET = 0.0393\,R_s\,\sqrt{T + 9.5} - 0.19\,R_s^{0.6}\,\varphi^{0.15} + 0.078\,(T + 20)\left(1 - \frac{RH}{100}\right)$	(96)	[122,123]

Table 3. *Cont.*

Radiation-Based Methods	Equation PET = f (Rs) *	Equation	Ref.
Valiantzas 2013 (3)	$PET = 0.0393\ R_s\ \sqrt{T+9.5} - 2.4\left(\frac{R_s}{R_a}\right)^2 - 0.024\ (T+20)\left(1-\frac{RH}{100}\right) + 0.1\ W_{aero}\ (T+20)\left(1-\frac{RH}{100}\right)$ $W_{aero} = \begin{cases} 0.78, & \text{for } RH > 65\% \\ 1.067, & \text{for } RH \le 65\% \end{cases}$	(97)	[133]
Milly and Dunne 2016	$PET = 0.8\ \frac{R_n - G}{\lambda}$	(98)	[134]
Ahooghal. et al. 2017 (2)	$PET = 0.79 \cdot 0.0393\ R_s\ \sqrt{T+9.5} - 1.15 \cdot 2.4\left(\frac{R_s}{R_a}\right)^2 - (-3.23) \cdot 0.024\ (T+20)\left(1-\frac{RH}{100}\right) + 0.32 \cdot 0.1\ W_{aero}\ (T+20)\left(1-\frac{RH}{100}\right),$ $W_{aero} = \begin{cases} 0.78, & \text{for } RH > 65\% \\ 1.067, & \text{for } RH \le 65\% \end{cases}$	(99)	[125]
Ahooghal. et al. 2017 (3)	$PET = 0.79 \cdot 0.0393\ R_s\ \sqrt{T+9.5} - 0.94 \cdot 0.19\ R_s^{0.6}\ \varphi^{0.15} + 1.37 \cdot 0.078\ (T+20)\left(1-\frac{RH}{100}\right)$	(100)	[125]

* where T, T_{max} and T_{min} represent the average, maximum and minimum daily air temperatures in °C, RH is the relative humidity in %, φ is the latitude in radians, Rs, Rn and Ra are the global solar, the net and the extraterrestrial radiation fluxes, respectively, in MJ m^{-2} day^{-1}, G is the soil heat flux in MJ m^{-2} day^{-1} (G = 0), Δ is the slope of the vapor pressure curve (kPa $°C^{-1}$), γ is the psychrometric constant (kPa $°C^{-1}$) and λ = 2.501–0.002361 T, in MJ kg^{-1}.

Table 4. Combination methods.

Combination Methods	Equation PET = f (Rs, u, T, RH) *	Equation	Ref.
FAO56-PM	$PET = \frac{0.408\ \Delta\ (R_n - G) + \gamma\ \frac{900}{T+273}\ u\ (e_s - e_a)}{\Delta + \gamma(1+0.34\ u)}$	Benchmark method	[11]
Penman 1963	$PET = \left[\frac{\Delta}{\Delta+\gamma}\ (R_n - G) + 6.43 \frac{\gamma}{\Delta+\gamma}\ (1 + 0.537\ u)(e_s - e_a)\right]\frac{1}{\lambda}$	(101)	[135]
Kimberly Penman 1972	$PET = \left[\frac{\Delta}{\Delta+\gamma}\ (R_n - G) + 6.43 \frac{\gamma}{\Delta+\gamma}\ (0.75 + 0.993\ u)(e_s - e_a)\right]\frac{1}{\lambda}$	(102)	[24]
mod. Makkink (Door. and Pr. 1977)	$PET = b\ \frac{\Delta}{\Delta+\gamma}\ \frac{R_s}{\lambda} - 0.3$, $b = 1.165 + 0.043\ u_b - 0.00575\ RH$	(103)	[19]
FAO24 Penman	$PET = \left[\frac{\Delta}{\Delta+\gamma}\ (R_n - G) + 6.43 \frac{\gamma}{\Delta+\gamma}\ (1 + 0.862\ u)(e_s - e_a)\right]\frac{1}{\lambda}$	(104)	[19]
FAO24 Radiation	$PET = b\left(\frac{\Delta}{\Delta+\gamma} R_s\right) - 0.3$ $b = 1.066 - 0.0013\ RH + 0.045\ u - 0.0002\ RH\ u - 0.0000315\ RH^2 - 0.0011\ u^2$	(105)	[19,136]
Jensen et al. 1990	$PET = \left[\frac{\Delta}{\Delta+\gamma}\ (R_n - G) + 6.43 \frac{\gamma}{\Delta+\gamma}\ (a_w + b_w\ u)(e_s - e_a)\right]\frac{1}{\lambda}.$ $a_w = 0.4 + 1.4\ e^{-\left(\frac{J-173}{58}\right)^2}$, $b_w = 0.605 + 0.345\ e^{-\left(\frac{J-243}{80}\right)^2}$	(106)	[21,22]
Linacre 1993	$PET = (0.015 + 0.00042\ T + 0.000001\ z)\ [9.26\ Rs - 40 + 2.5(1 - 0.000087z)\ u\ (T - T_d)]$	(107)	[137]
Wright 1996	$PET = \left[\frac{\Delta}{\Delta+\gamma}\ (R_n - G) + 6.43 \frac{\gamma}{\Delta+\gamma}\ (a_w + b_w\ u)(e_s - e_a)\right]\frac{1}{\lambda}$ $a_w = 0.3 + 0.58\ e^{-\left(\frac{J-170}{45}\right)^2}$, $b_w = 0.32 + 0.54\ e^{-\left(\frac{J-228}{67}\right)^2}$	(108)	[23]
Valiantzas 2006 (2)	$PET = 0.038\ R_s\ \sqrt{T+9.5} - 2.4\left(\frac{R_s}{R_a}\right)^2 + 0.048\ (T+20)(1-\frac{RH}{100})\ (0.5 + 0.536u) + 0.00012\ z$	(109)	[132]
Valiantzas 2013 (4)	$PET = 0.0393\ R_s\ \sqrt{T+9.5} - 0.19\ R_s^{0.6}\ \varphi^{0.15} + 0.048\ (T+20)(1-\frac{RH}{100})\ u^{0.7}$	(110)	[122,123]
Valiantzas 2013 (5)	$PET = 0.0393\ R_s\ \sqrt{T+9.5} - 2.4\left(\frac{R_s}{R_a}\right)^2 - 0.024\ (T+20)(1-\frac{RH}{100}) + 0.066\ W_{aero}\ (T+20)(1-\frac{RH}{100})\ u^{0.6}$, $W_{aero} = \begin{cases} 0.78, & \text{for } RH > 65\% \\ 1.067, & \text{for } RH \le 65\% \end{cases}$	(111)	[133]
	PET = f (Rs, u, T) *		
Valiantzas 2013 (6)	$PET = 0.0393\ R_s\ \sqrt{T+9.5} - 0.19\ R_s^{0.6}\ \varphi^{0.15} + 0.0037\ (T+20)\ (1.12\ T - T_{min} - 2)^{0.7} u^{0.7}$	(112)	[122,123]

* where T and T_{min} are the average and minimum daily air temperatures in °C, T_d is the dewpoint in °C, RH is the relative humidity in %, φ is the latitude in radians, z is the altitude in m, Rs, Rn and Ra are the global solar, the net and the extraterrestrial radiation fluxes in MJ m^{-2} day^{-1}, G is the soil heat flux in MJ m^{-2} day^{-1} (G = 0), Δ is slope of the vapor pressure curve (kPa $°C^{-1}$), γ is the psychrometric constant (kPa $°C^{-1}$), J is the day of the year, λ= 2.501 − 0.002361 T, in MJ kg^{-1}, e_s and e_a are the saturation and actual vapor pressures in kPa, u is the windspeed at height 2m in m/s and u_b is the windspeed in Beaufort.

The equations of all models used in this work are presented for each group below. Details for the estimation of the parameters used in the equations can be found in Allen et al. [11] and Proutsos et al. [138,139]. The PET estimates with negative values were excluded for the analysis.

2.3. Statistical Indices and Ranking

To compare the estimations of PET by the different models against the estimates by FAO56-PM, the commonly used coefficients of the linear regression y = ax + b were employed: slope a, intercept b and coefficient of determination R^2. Four additional statistical measures recommended by Fox [140] were applied: the mean bias error (MBE) to assess the bias, the variance of the differences distribution s_d^2 to evaluate the variability of the differences between the PET values around the MBE, the mean absolute error (MAE) and the root mean square error (RMSE) to express the average difference. The index of agreement (d) was also used to make the cross-comparison between the models [141–143]. The analytic equations for the estimation of the indices are presented in Appendix A (Equations (A1)–(A5)).

To rank the methods, the above indices were used, and through a standardization procedure proposed by Aschonitis et al. [144] and also described in Rahimikhoob et al. [145], the standardized ranking performance index (sRPI) was estimated by the equations presented in Appendix A (Equations (A6)–(A9)).

3. Results

The micrometeorological stations of this study were installed above grass-covered irrigated surfaces inside the urban green spaces. Such surface characteristics allow the accurate estimation of PET by the application of the Penman–Monteith method considering that the measured meteorological parameters are highly affected by the substrate above which the measurements are taken [8].

The PET estimates with the FAO56-PM method for the two cities present higher values for the southern site of Heraklion with an annual average of 3.37 ± 1.92 mm d^{-1}, which is slightly higher compared to the respective values of Amaroussion (3.10 ± 1.92 mm d^{-1}). Both sites present high seasonal variability with ET values ranging from 1.44 ± 0.49 mm d^{-1} in winter to 5.87 ± 0.77 mm d^{-1} in summer in Heraklion and from 1.05 ± 0.41 mm d^{-1} in winter to 5.48 ± 1.00 mm d^{-1} in summer in Amaroussion. The day-to-day and monthly values are even more variable, as depicted in Figure 3.

The daily values of Figure 3 were used as the basis for comparing PET with the respective estimates by the application of other methods. The results per method category follow.

3.1. Mass Transfer-Based Methods

The comparative presentation of the PET estimates produced by the application of the 12 mass transfer methods (Equations (1)–(12)) against the PET values by the FAO56-PM method for the two urban green areas are presented in Figure A1, Appendix B, along with the regression line statistics. The values dispersion confirms the higher PET in Heraklion compared to Amaroussion. The combined assessment of Figure A1 (Appendix B) and Table A1 (Appendix C) indicates that in general, Mahringer 1970 (Equation (10)) followed by Trabert 1886 (Equation (3)) and Linacre 1992 (Equation (12)) are the best performing mass transfer-based methods in Heraklion, ranking 46th, 47th and 52nd among all 112 examined models with sRPI scores of 0.827, 0.825 and 0.813, respectively (Table 5), whereas Fitzerald 1986 (Equation (2)) and Brockamp and Wenner 1963 (Equation (8)) are the worst (112th with sRPI = 0.177 and 111th with sRPI = 0.292, respectively, at the overall ranking). Mahringer 1970 (Equation (10)) produced the minimum MBE (−0.029 mm d^{-1}) and the best slope a value (1.015) compared to all other mass transfer methods, whereas its mean value (3.234 ± 2.264 mm d^{-1}) is quite close to FAO56-PM (3.266 ± 1.910 mm d^{-1}) and only underestimated by −0.98%. Trabert 1886 (Equation (3)) had the best d index (0.974) and Linacre 1992 (Equation (12)) had the smallest RMSE (0.977 mm d^{-1}), smallest MAE (0.801), smallest sd^2 (0.789 mm d^{-1}), and best R^2 (0.796) among all mass transfer-based method in Heraklion.

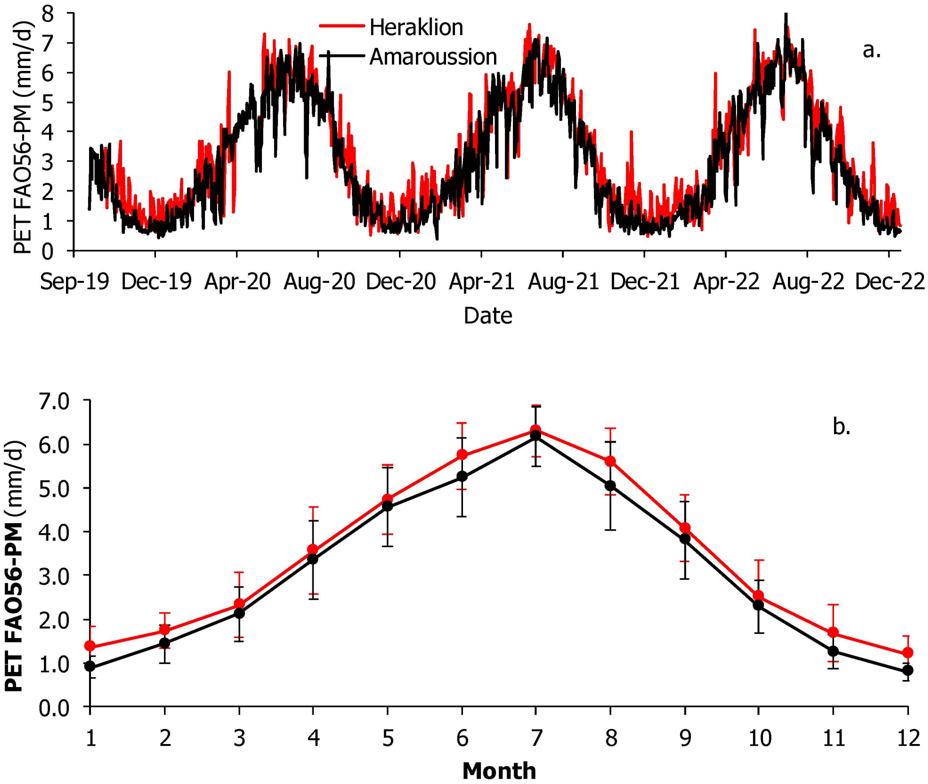

Figure 3. (**a**) Daily and (**b**) monthly PET, estimated by the FAO56-PM method at two urban green spaces in the cities of Heraklion and Amaroussion. Vertical lines show the standard deviations.

Table 5. Statistical indices (mean, slope a, intercept b, and coefficient of determination R^2, of the linear regression y = ax + b, mean bias error (MBE), root mean square error (RMSE), mean absolute error (MAE), standard deviation square (sd^2), and index of agreement d) and ranking (sRPI score and rank) based on the optimum values of the statistical indices for the five best mass transfer-based PET modes compared to the FAO56-PM base method in the two urban green sites of Heraklion and Amaroussion.

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	d	R^2	sRPI	Rank
Heraklion												
FAO56-PM	1139	3.266										
10. Mahringer 1970	1139	3.234	1.015	−0.087	−0.029	1.158	0.834	1.332	0.919	0.738	0.827	46
3. Trabert 1896	1139	3.470	1.091	−0.094	0.207	1.270	0.882	1.569	0.974	0.738	0.825	47
12. Linacre 1992	1138	3.669	0.895	0.738	0.403	0.977	0.801	0.789	0.946	0.796	0.813	52
9. WMO 1966	1139	2.594	0.785	0.025	−0.670	1.212	0.913	1.002	0.964	0.729	0.798	55
7. Albrecht 1950	1139	3.634	1.080	0.105	0.371	1.255	0.830	1.437	0.898	0.750	0.796	56
Amaroussion												
FAO56-PM	1195	2.969										
9. WMO 1966	1195	2.465	0.915	−0.259	−0.670	0.923	0.693	0.592	0.982	0.844	0.853	40
12. Linacre 1992	1187	3.620	1.062	0.446	0.403	1.076	0.903	0.761	0.957	0.847	0.831	44
10. Mahringer 1970	1195	3.005	1.171	−0.478	−0.029	1.042	0.726	1.085	0.943	0.836	0.826	50
3. Trabert 1896	1195	3.225	1.259	−0.514	0.207	1.197	0.786	1.368	0.981	0.836	0.817	56
7. Albrecht 1950	1195	3.647	1.398	−0.506	0.371	1.562	0.981	1.985	0.902	0.834	0.740	84

In the green space of Amaroussion, however, WMO 1966 (Equation (9)), Linacre 1992 (Equation (12)) and Mahringer 1970 (Equation (10)) were the best-performing mass transfer-based methods (Table 5), ranking 40th, 44th and 50th, with sRPI scores of 0.853, 0.831 and 0.826, respectively. The worst methods were also Fitzerald 1986 (Equation (2)) and Brockamp and Wenner 1963 (Equation (8)), as in Heraklion, which were ranked 112th and 111th among all methods with sRPI values of 0.189 and 0.300, respectively. WMO 1966 (Equation (9)) produced the minimum MAE (0.693 mm d^{-1}), RMSE (0.923 mm d^{-1}) and the best sd^2 (0.592 mm d^{-1}) and d (0.982) values, but its average PET estimate (2.465 $\pm$ 1.905 mm d^{-1}) was -17% smaller compared to FAO56-PM (2.969 $\pm$ 1.904 mm d^{-1}). Linacre 1992 (Equation (12)) had the best slope a value (1.062).

The ranking scores for both sites (derived as averages of the sRPI) suggest that Mahgringer 1970 (Equation (10)) had the best performance among the mass transfer methods, followed by WMO 1966 (Equation (9)) and Linacre 1992 (Equation (12)), which ranked 45th, 47th and 49th among the 112 examined models with sRPI values of 0.827, 0.826 and 0.822, respectively. The correlations of the five best-performing models of this category are presented in Figure 4.

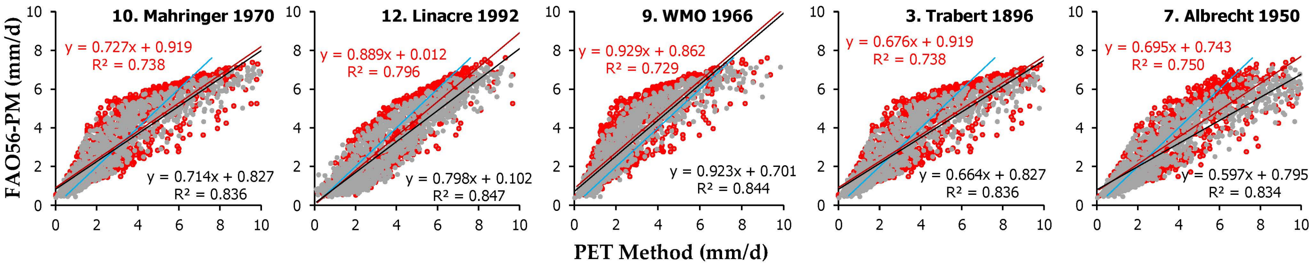

Figure 4. Correlation between daily PET values estimated by the best five mass transfer methods (x-axis) against the benchmark method of FAO56-PM (y-axis) for the two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

3.2. Temperature-Based Methods

The PET estimates by the application of 48 temperature-based empirical models (Equations (13)–(60)) are presented against the respective daily values by FAO56-PM for the two sites in Figures A2 and A3 (Appendix B). The general patterns indicate generally higher estimates of the method of this category in Heraklion compared to the site in Amaroussion. The statistics from the comparisons for all methods in both sites are presented in Table A2 (Appendix C).

In Heraklion, Ahooghalaandari et al. 2016 (3) (Equation (58)) was the best temperature-based method, ranking 27th among all examined models with sRPI = 0.889, followed by Xu and Singh 2001 (2) (Equation (28)) and Xu and Singh 2001 (1) (Equation (27)), which ranked 34th and 37th, with sRPI values of 0.876 and 0.869, respectively. Ahooghalaandari et al. 2016 (3) (Equation (58)) had the minimum MAE (0.562 mm d^{-1}) and the best d (0.966) values, and they produced an average PET (3.609 $\pm$ 2.451 mm d^{-1}) +10% higher compared to FAO56-PM. The worst temperature-based methods for the site were by Antal 1968 (Equation (50)) and Smith and Stopp 1978 (Equation (21)), which ranked 109th and 108th among the 112 models.

Ahooghalaandari et al. 2016 (3) (Equation (58)) was also the best method for the site of Amaroussion, ranking 26th among the 112 tested models with a similar sRPI (0.887), which was followed by Oudin 2005 (Equation (36)) and Xu and Singh 2001 (2) (Equation (28)) ranking 27th (sRPI = 0.885) and 36th (sRPI = 0.861), respectively. The worst performing were the methods of Xu and Singh 2001 (5) (Equation (53)) and Antal 1968 (Equation (50)), which were ranked 110th and 109th with sRPI scores 0.407 and 0.489, respectively. The application of Ahooghalaandari et al. 2016 (3) (Equation (58)) produced an average PET of 3.607 $\pm$ 2.720 mm d^{-1}, which was +21% higher compared to FAO56-PM.

The statistical indices and the ranking (among the 112 examined models) for the five best-performing temperature-based methods for each site are shown in Table 6.

Table 6. Statistical indices (mean, slope a, intercept b, and coefficient of determination R^2, of the linear regression y = ax + b, mean bias error (MBE), root mean square error (RMSE), mean absolute error (MAE), standard deviation square (sd^2), and index of agreement d) and ranking (sRPI Score and Rank) based on the optimum values of the statistical indices for the best five temperature-based PET models compared to the benchmark method of FAO56-PM in the two urban green sites of Heraklion and Amaroussion.

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	D	R^2	sRPI	Rank
Heraklion												
FAO56-PM	1139	3.266										
58. Ahoogh. et al. 2016 (3)	1139	3.609	0.916	0.569	0.346	0.717	0.562	0.379	0.966	0.897	0.889	27
28. Xu and Singh 2001 (2)	1139	3.171	0.934	0.100	−0.092	0.877	0.718	0.731	0.950	0.816	0.876	34
27. Xu and Singh 2001 (1)	1139	3.114	0.926	0.068	−0.149	0.869	0.706	0.702	0.931	0.821	0.869	37
36. Oudin 2005	1139	3.013	0.755	0.516	−0.251	0.709	0.578	0.392	0.935	0.923	0.869	38
37. Castañ. and Rao 2005 (1)	1139	3.602	0.800	0.960	0.339	0.743	0.610	0.426	0.943	0.893	0.841	43
Amaroussion												
FAO56-PM	1195	2.969										
58. Ahoogh. et al. 2016 (3)	1195	3.607	1.118	0.240	0.346	0.917	0.719	0.493	0.964	0.920	0.887	26
36. Oudin 2005	1195	2.878	0.831	0.382	−0.251	0.642	0.501	0.399	0.957	0.904	0.885	27
28. Xu and Singh 2001 (2)	1195	3.023	1.008	0.010	−0.092	0.938	0.753	0.880	0.951	0.811	0.861	36
27. Xu and Singh 2001 (1)	1195	2.974	1.002	−0.022	−0.149	0.921	0.737	0.849	0.939	0.815	0.857	37
34. Trajkovic 2005 (1)	1195	2.852	0.844	0.321	−0.345	0.837	0.666	0.681	0.946	0.821	0.832	42

For both sites, Ahooghalaandari et al. 2016 (3) (Equation (58)), Oudin 2005 (Equation (36)) and Xu and Singh 2001 (2) (Equation (28)) are ranked higher among the temperature-based PET methods (27th, 31st and 35th, respectively, at the overall ranking) with sRPI scores of 0.888, 0.877 and 0.869, respectively. It is worth noting that all 48 temperature-based methods received sRPI scores ranging from 0.487 to 0.888, and 15 of them had sRPI values greater than 0.800, whereas 4 out of the 12 mass transfer-based methods had sRPIs greater than 0.800. The correlations of the daily value estimated by the five best-performing methods of this category against the FAO56-PM method are presented for both sites in Figure 5.

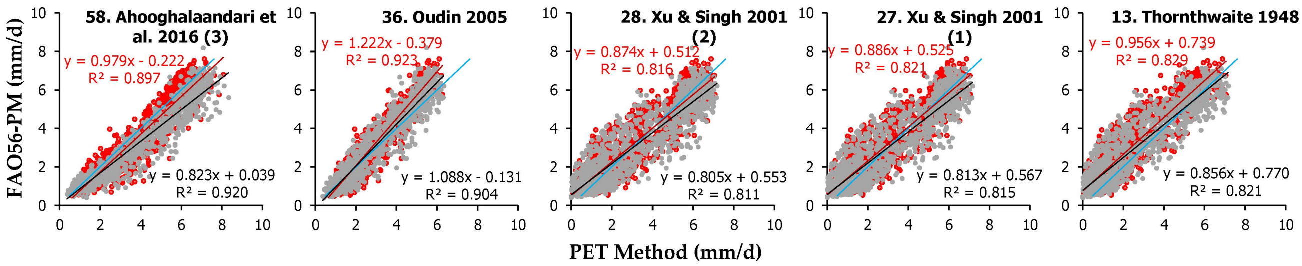

Figure 5. Correlation between daily PET values estimated by the best-performing temperature-based methods (x-axis) of the general forms PET = f (T, RH or PR) against the benchmark method of FAO56-PM (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

3.3. Radiation-Based Methods

The 40 radiation-based methods (Equations (61)–(100)) examined in the two study sites produced daily estimates presented in conjunction with the FAO56-PM estimates in Figures A4 and A5 (Appendix B). The comparison between the values produced the statistics presented in Table A3 (Appendix C). The statistical indices for the five best-performing radiation-based methods in each site are presented in Table 7.

Table 7. Statistical indices (mean, slope a, intercept b, and coefficient of determination R^2, of the linear regression y = ax + b, mean bias error (MBE), root mean square error (RMSE), mean absolute error (MAE), standard deviation square (sd^2), and index of agreement d) and ranking (sRPI Score and Rank) based on the optimum values of the statistical indices for the five better-performing radiation-based models for the estimation of PET compared to the benchmark method of FAO56-PM in the two urban green sites of Heraklion and Amaroussion.

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	d	R^2	sRPI	Rank
Heraklion												
FAO56-PM	1139	3.266										
99. Ahoogh. Et al. 2017 (2)	1139	3.518	0.977	0.243	0.255	0.534	0.416	0.178	0.984	0.954	0.955	4
79. Castañ. and Rao 2005 (2)	1138	3.243	0.974	−0.007	−0.022	0.683	0.553	0.394	0.979	0.899	0.943	8
85. Priestley and Taylor 1972	1139	3.249	1.058	−0.279	−0.014	0.639	0.499	0.332	0.986	0.929	0.941	9
100. Ahoogh. Et al. 2017 (3)	1139	3.552	0.980	0.266	0.289	0.598	0.493	0.237	0.976	0.939	0.939	10
86. Abtew 1996 (4)	1139	3.048	0.991	−0.261	−0.215	0.660	0.486	0.281	0.969	0.929	0.935	11
Amaroussion												
FAO56-PM	1195	2.969										
85. Priestley and Taylor 1972	1195	3.027	1.018	−0.065	−0.014	0.486	0.375	0.241	0.992	0.958	0.972	2
86. Abtew 1996 (4)	1195	2.841	0.954	−0.061	−0.215	0.513	0.374	0.229	0.979	0.958	0.956	6
99. Ahoogh. Et al. 2017 (2)	1195	3.474	1.158	−0.045	0.255	0.731	0.562	0.361	0.978	0.964	0.933	9
79. Castañ. and Rao 2005 (2)	1194	3.188	0.926	0.373	−0.022	0.572	0.486	0.308	0.984	0.934	0.930	10
71. Hansen 1984	1195	3.299	0.927	0.491	0.090	0.609	0.522	0.301	0.977	0.934	0.916	12

In Heraklion, the best-performing radiation-based methods were Ahooghalaandari et al. 2017 (2) (Equations (99)) followed by Castañeda and Rao 2005 (2) (Equation (79)) and Priestley and Taylor 1972 (Equation (85)), which were ranked 4th, 8th and 9th among all 112 models, with sRPI scores of 0.955, 0.943 and 0.941, and mean PET estimates +7.7%, −0.7% and −0.5% different compared to FAO56-PM, respectively. Ahooghalaandari et al. 2017 (2) (Equation (99)) presented minimum RMSE (0.534 mm d^{-1}), MAE (0.416 mm d^{-1}) and sd^2 (0.178), whereas Castañeda and Rao 2005 (2) (Equation (79)) had the minimum offset b (−0.007 mm d^{-1}) and Priestley and Taylor 1972 (Equation (85)) had the minimum MBE (−0.014 mm d^{-1}) and the best d (0.986) among the radiation-based models. The worst methods of this category in Heraklion were Tabari and Talaee 2011 (3) (Equation (94)) ranking 110th sRPI = 0.495 and Xu and Singh 2000 (Equation (87)) ranking 103rd with sRPI = 0.603, producing PET means −30.7% and +67.6% different compared to FAO56-PM. In general, however, the radiation methods in Heraklion had a good performance in most cases, since the produced PET means were less than 10% different from FAO56-PM in 19 out of the 40 methods.

In Amaroussion, Priestley and Taylor 1972 (Equation (85)) was ranked first among the radiation-based methods (2nd among all 112 models, with sPRI = 0.972), followed by Abtew 1996 (4) (Equation (86)) and Ahooghalaandari et al. 2017 (2) (Equation (99)), which were ranked 6th (sPRI = 0.956) and 9th (sPRI = 0.933) among all examined models. These methods produced mean PET values +2.00%, −4.3% and +17% different compared to FAO56-PM, respectively. Priestley and Taylor 1972 (Equation (85)) showed the best MBE (−0.014 mm d^{-1}), RMSE (0.486 mm d^{-1}) and d (0.992) values, whereas Abtew 1996 (4) (Equation (86)) had the best MAE (0.374 mm d^{-1}) and sd^2 (0.229 mm d^{-1}) and Ahooghalaandari et al. 2017 (2) (Equation (99)) presented the minimum offset b (−0.045 mm d^{-1}) among all radiation-based methods. The worst models in Amaroussion were Tabari and Talaee 2011 (3) (Equation (94)) and Xu and Singh 2000 (Equation (87)), ranking 103rd and 99th, respectively, among all examined 112 methods, with sRPI values of 0.591 and 0.621. These methods' mean PET values were +71.7% and −28.7% different compared to FAO56-PM. The overall performance of radiation-based methods in Amaroussion can be considered satisfactory, considering that 28 out of the 40 equations presented sRPI values higher than 0.800, whereas 15 of them had sRPI > 0.900.

The ranking derived from the statistics of both sites suggests that Priestley and Taylor 1972 (Equation (85)) ranking 5th with sRPI = 0.957, Abtew 1996 (4) (Equation (86)) ranking 7th with sRPI = 0.946 and Ahooghalaandari et al. 2017 (2) (Equation (99)) ranking 9th with sRPI = 0.944 between all 112 models were the best radiation-based methods, whereas Tabari and Talaee 2011 (3) (Equation (94)) ranking 107th and Xu and Singh 2000 (Equation (87)) ranking 102nd were the two worst methods with average sPRI values from both sites 0.543 and 0.612, respectively. The best five performing methods for both sites (according to the average sRPI scores) are depicted in Figure 6.

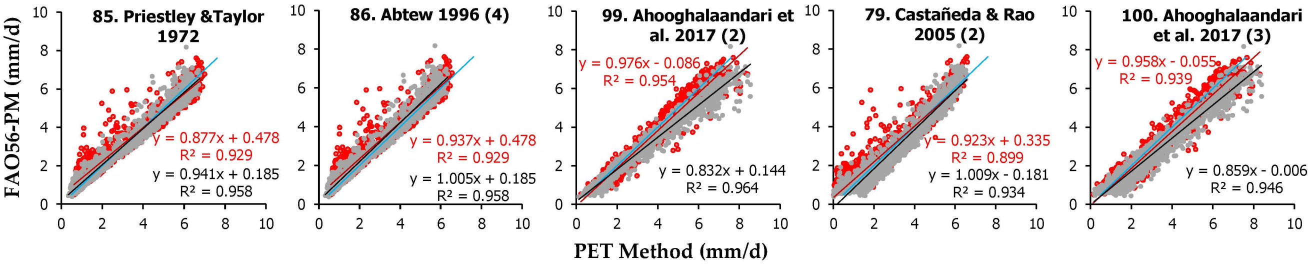

Figure 6. Correlation between daily ET values estimated by the five best-performing radiation-based methods (x-axis), against the FAO56-PM benchmark method (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

3.4. Combination Methods

The PET estimates from the 12 combination methods (Equations (101)–(112)) assessed in this study are depicted against the PET daily values in Figure A6 (Appendix B), whereas the statistical indices values used for the ranking of the methods are presented in Table A4 (Appendix C). The graphs and the statistical results suggest that this category of models produces good PET estimates compared to all other categories.

The statistics for five best-performing methods of this PET model category are presented for both sites in Table 8. The assessment of all combination methods statistics, presented also in Table A4 (Appendix C), indicates that Wright 1996 (Equation (108)) is the best-performing model in Heraklion, followed by Valiantzas 2006 (2) (Equation (109)) and Jensen et al. 1990 (Equation (106)). Wright 1996 (Equation (108)) is ranked 1st among all examined 112 models and had the best sRPI (0.987), whereas it produced an average PET that was only −0.8% lower compared to FAO56-PM. This method presented the minimum RMSE (0.446 mm d^{-1}) and MAE (0.315 mm d^{-1}) and also the best slope a (1.005) and d (0.989) values. Valiantzas 2006 (2) (Equation (109)) and Jensen et al. 1990 (Equation (106)) methods were ranked 2nd and 3rd, respectively, among all 112 examined models and had also high sRPI values (0.970 and 0.963). However, the produced mean PET values were about +11% higher compared to FAO56-PM. However, Valiantzas 2006 (2) (Equation (109)) presented the minimum offset b (−0.008 mm d^{-1}) and sd^2 (0.078 mm d^{-1}) in Heraklion not only among the combination but among all 112 methods. The worst-performing methods for the site were FAO24 Radiation (Equation (105)) followed by the modified Makkink by Doorenbos and Pruitt 1977 (Equation (103)), which were ranked 58th and 53rd with sRPI values of 0.792 and 0.813, respectively. The mean PET values of these methods were +25.3% and +20.4% higher compared to FAO56-PM.

In Amaroussion, Wright 1996 (Equation (108)) was the best-performing model ranked 1st with sRPI = 0.992 followed by Jensen et al. 1990 (Equation (106)), Valiantzas 2006 (2) (Equation (109)), and Valiantzas 2013 (6) (Equation (112)), which were ranked 3rd, 4th and 5th with similar sRPI values (0.963, 0.962 and 0.962). Wright 1996 (Equation (108)) showed the best slope a (0.984) and d (0.991) and the minimum RMSE (0.393 mm d^{-1}), MAE (0.264 mm d^{-1}) and sd^2 (0.159 mm d^{-1}) values, producing a mean PET estimate +0.97% higher compared to FAO56-PM. Also, in Amaroussion, Jensen et al. 1990 (Equation (106)) had the best offset b (0.003), but its mean PET was +12.3% higher compared to FAO56-

PM. As in Heraklion, the worst combination methods for Amaroussion were also FAO24 Radiation (Equation (105)) followed by the modified Makkink by Doorenbos and Pruitt 1977 (Equation (103)), which ranked 54th and 49th, respectively, among the 112 models, presenting relatively low sRPI values (0.819 and 0.828) and also mean PET values +37.3% and +33.1% higher compared to FAO56-PM.

Table 8. Statistical indices (mean, slope a, intercept b, and coefficient of determination R^2 of the linear regression y = ax + b, mean bias error (MBE), root mean square error (RMSE), mean absolute error (MAE), standard deviation square (sd^2) and index of agreement d) and ranking (sRPI Score and Rank) based on the optimum values of the statistical indices for the five better-performing combination PET models compared to the FAO56-PM benchmark method in the two urban green sites of Heraklion and Amaroussion.

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	D	R^2	sRPI	Rank
Heraklion												
FAO56-PM	1139	3.266										
108. Wright 1996	1139	3.239	1.005	−0.134	−0.024	0.446	0.315	0.099	0.989	0.976	0.987	1
109. Valiantzas 2006 (2)	1139	3.615	1.081	−0.008	0.352	0.479	0.411	0.078	0.986	0.990	0.970	2
106. Jensen et al. 1990	1139	3.629	1.104	−0.067	0.365	0.524	0.377	0.116	0.989	0.985	0.963	3
112. Valiantzas 2013 (6)	1136	3.251	1.016	−0.170	−0.017	0.604	0.488	0.263	0.979	0.937	0.954	5
110. Valiantzas 2013 (4)	1138	3.590	1.120	−0.164	0.324	0.553	0.499	0.167	0.983	0.977	0.947	6
Amaroussion												
FAO56-PM	1195	2.969										
108. Wright 1996	1195	2.998	0.984	−0.010	−0.024	0.393	0.264	0.159	0.991	0.983	0.992	1
106. Jensen et al. 1990	1195	3.336	1.093	0.003	0.365	0.529	0.370	0.209	0.988	0.982	0.963	3
112. Valiantzas 2013 (6)	1185	3.098	0.969	0.110	−0.017	0.502	0.422	0.260	0.985	0.957	0.962	4
109. Valiantzas 2006 (2)	1195	3.391	1.114	−0.006	0.352	0.528	0.443	0.176	0.983	0.993	0.962	5
110. Valiantzas 2013 (4)	1194	3.361	1.099	0.007	0.324	0.570	0.513	0.244	0.982	0.976	0.952	7

The combination methods ranking for both sites depicts Wright 1996 (Equation (108)) as the best combination model, followed by Valiantzas 2006 (2) (Equation (109)) and Jensen et al. 1990 (Equation (106)). These models were ranked 1st, 2nd and 3rd among all 112 investigated methods and received the highest sRPI scores (average sRPI scores from both sites: 0.990, 0.966 and 0.963, respectively). The daily PET estimates by the five best-performing combination methods against FAO56-PM are presented in Figure 7. In all cases, however, the combination methods performed better compared than all other method categories, since they presented high sRPI scores (higher than 0.806), which is rather expected considering the higher number of input parameters required for the application of the combination equations.

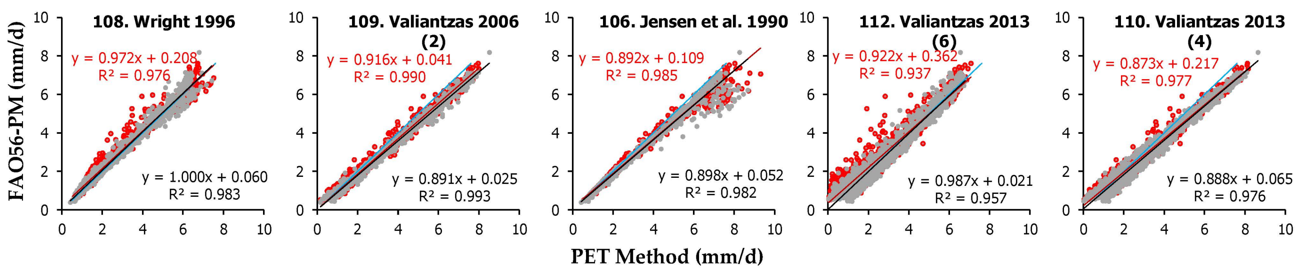

Figure 7. Correlation between daily PET values estimated by the five better-performing combination methods (x-axis) against the FAO56-PM benchmark method (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

3.5. Models Adjustment

The local calibration of the empirical models for the PET estimation is suggested in most research works and is also imposed by the results of the present study. In this work, an adjustment of the general forms of mass transfer, temperature and radiation-based equations was performed for local use in the territories of our study sites. Based on the daily data from both stations, 15 adjusted PET models were produced following the general forms of several widely used equations. For example, the mass transfer model proposed by Dalton 1802 (Equation (1)), Fitzgerald 1886 (Equation (2)), Meyer 1926 (Equation (4)), Rohwer 1931 (Equation (5)), Albrecht 1950 (Equation (7)) and WMO 1966 (Equation (9)) follow the general form of PET = (a + bu) (e_s – e_a). The adjusted values of a and b, based on the data from the two stations, are presented in Table 9. Similarly, other widely used models were adjusted for local use, and the new models are also presented in Table 9. The performance of the adjusted equations (Equations (113)–(127)) is evaluated following the estimation of statistical indices and ranking as above. The daily PET estimates for the new models are presented for the two sites along with the respective PET values by the FAO56-PM method in Figure 8.

Table 9. Adjusted PET models for local use in Heraklion and Amaroussion.

Adjusted Models *		Model Category	Equation
Model 1	$PET_{adj} = (1.895 + 0.716\ u)\ (e_s - e_a)$	Mass transfer-based, PET = f (u, T, RH)	(113)
Model 2	$PET_{adj} = 2.7\ u^{0.289}\ (e_s - e_a)$	Mass transfer-based, PET = f (u, T, RH)	(114)
Model 3	$PET_{adj} = 0.026\ T^{1.621}$	Temperature-based, PET = f (T)	(115)
Model 4	$PET_{adj} = 0.01357\ (T + 3.167)\ (T_{max} - T_{min})^{-0.07}\ R_a$	Temperature-based, PET = f (T)	(116)
Model 5	$PET_{adj} = 9.498\ \frac{T}{RH}$	Temperature-based, PET = f (T, RH)	(117)
Model 6	$PET_{adj} = 0.135\ R_a + 0.235\ T\left(1 - \frac{RH}{100}\right)$	Temperature-based, PET = f (T, RH)	(118)
Model 7	$PET_{adj} = 0.471 \frac{R_s}{\lambda}$	Radiation-based, PET = f (Rs)	(119)
Model 8	$PET_{adj} = 1.239 \frac{\Delta}{\Delta + \gamma} \frac{R_n - G}{\lambda}$	Radiation-based, PET = f (Rs, T, RH)	(120)
Model 9	$PET_{adj} = 0.89 \frac{R_n - G}{\lambda}$	Radiation-based, PET = f (Rs, T)	(121)
Model 10	$PET_{adj} = 1.146 \frac{\Delta}{\Delta + \gamma} \frac{R_n - G}{\lambda} + 0.326$	Radiation-based, PET = f (Rs, T, RH)	(122)
Model 11	$PET_{adj} = \frac{R_s}{\lambda}(0.013T + 0.186)$	Radiation-based, PET = f (Rs, T)	(123)
Model 12	$PET_{adj} = 0.147\ R_s + 0.110\ T - 1.359$	Radiation-based, PET = f (Rs, T)	(124)
Model 13	$PET_{adj} = 0.280\ R_n + 0.081\ T - 0.791$	Radiation-based, PET = f (Rs, T)	(125)
Model 14	$PET_{adj} = 0.443 + 0.544\ C_2 - 0.010\ C_1 + 0.032\ C_1\ C_2$	Radiation-based, PET = f (Rs, T, RH)	(126)
Model 15	$PET_{adj} = 1.378\ (e_s - e_a)^{0.379}\left(1 - \frac{T}{273}\right)^{11.539}$	Temperature-based, PET = f (T, RH)	(127)

* where T, T_{max} and T_{min} are the average, maximum and minimum daily air temperatures in °C, RH is the relative humidity in %, Rs and Rn are the global solar and net radiation fluxes in MJ m^{-2} day^{-1}, Ra is the extraterrestrial radiation in mm d^{-1}, Δ is the slope of the vapor pressure curve (kPa $°C^{-1}$), γ is the psychrometric constant (kPa $°C^{-1}$), λ = 2.501 – 0.002361 T, in MJ kg^{-1}, e_s and e_a are the saturation and actual vapor pressures in kPa, u is the windspeed at height 2 m in m s^{-1}, C_1 and C_2 are factors presented in Table 3, Equation (92)).

The daily PET dispersion of values depicted in Figure 8 in association with the statistical indices of the new methods and the ranking with respect to all 127 models (112 original and 15 adjusted) in both sites that are presented in Table 10 suggest that the adjusted models performed better compared to the original equations.

More specifically, the mass transfer models 1 (Equation (113)) and 2 (Equation (114)) were ranked 66th and 64th (with sRPI scores of 0.803 and 0.813), respectively, among all 127 models, in Heraklion, whereas in Amaroussion, they performed better (ranked 42nd and 44th, with similar sRPI scores of 0.867 and 0.866, respectively). Similarly, the adjusted temperature-based models 3, 4, 5, 6 and 15 (Equations (115)–(118) and (127)) were ranked between 26th and 97th with scores ranging from 0.701 to 0.916, in Heraklion, among which model 4 performed the best (Equation (116)), which is actually an adjustment of the Hargreaves and Samani method. The temperature-based adjusted models in Amaroussion presented also good performance, and they ranked between 21st and 84th among the 127 methods, with sRPI ranging from 0.783 to 0.913, among which model

4 performed the best (Equation (116)). Finally, the radiation-based adjusted models 7–14 (Equations (119)–(126)) produced in general accurate estimates. Their sRPI scores, in Heraklion, ranged from 0.851 to 0.960, resulting in ranks varying from 4th to 50th, among which model 10 performed the best (Equation (122)). In Amaroussion, model 8 had an excellent behavior, ranking 2nd among all 127 methods, with a high sRPI value (0.972), whereas the rest of the radiation-based adjusted models also received high sRPI scores ranging from 0.819 to 0.972, with ranks varying between 7th and 67th.

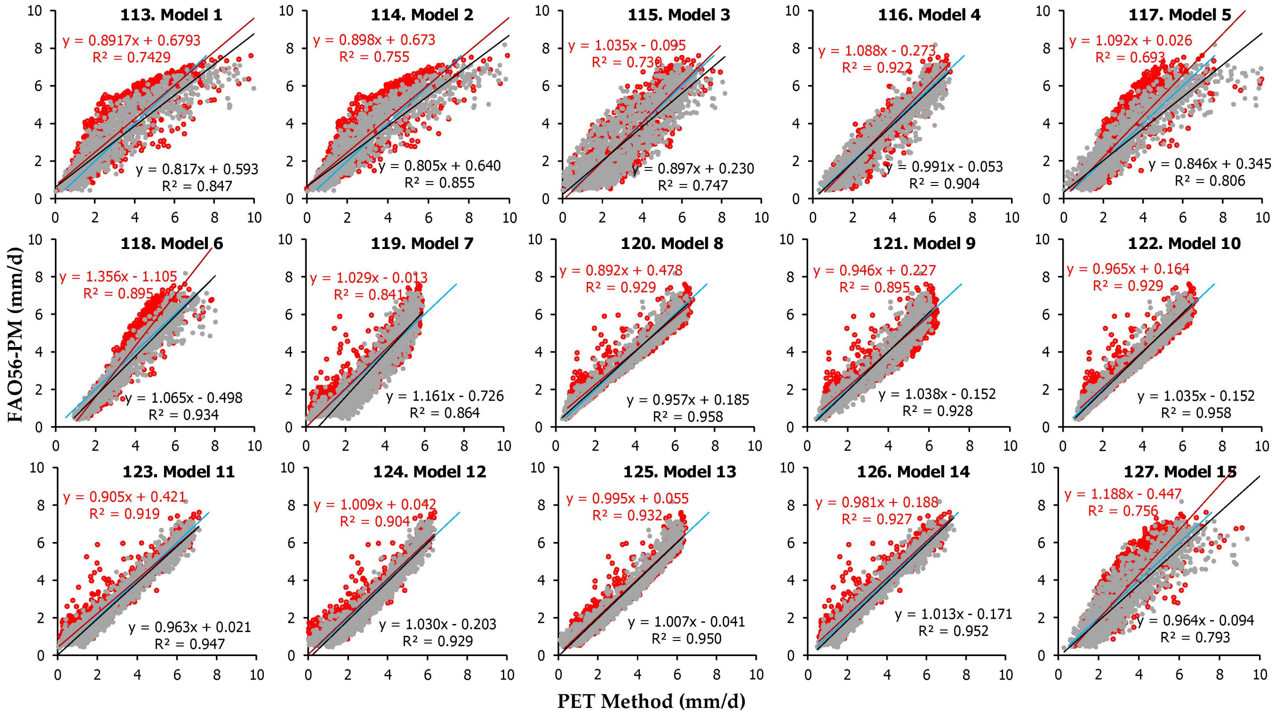

Figure 8. Correlation between daily PET estimated by the adjusted models (x-axis) and the benchmark method of FAO56-PM (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line depicts the 1:1 regression.

Table 10. Statistical indices (mean, slope a, intercept b, and coefficient of determination R^2, of the linear regression y = ax + b, mean bias error (MBE), root mean square error (RMSE), mean absolute error (MAE), standard deviation square (sd^2), and index of agreement d) and ranking (sRPI Score and Rank) based on the optimum values of the statistical indices for the 15 adjusted PET models (Equations (113)–(127)) compared to the FAOs56-PM in the urban green sites of Heraklion and Amaroussion.

Adjusted PET Model	N	Mean	a	b	MBE	RMSE	MAE	sd^2	d	R^2	sRPI	Rank
Heraklion												
FAO56-PM	1139	3.266										
113. Model 1	1138	2.901	0.833	0.180	−0.365	1.054	0.778	0.977	0.918	0.743	0.803	66
114. Model 2	1138	2.887	0.841	0.142	−0.379	1.036	0.766	0.929	0.924	0.755	0.813	64
115. Model 3	1138	3.248	0.706	0.943	−0.018	0.993	0.838	0.986	0.913	0.730	0.755	82
116. Model 4	1138	3.252	0.847	0.486	−0.014	0.555	0.432	0.307	0.970	0.922	0.916	26
117. Model 5	1138	2.967	0.635	0.894	−0.299	1.107	0.877	1.136	0.868	0.693	0.701	97
118. Model 6	1138	3.223	0.660	1.069	−0.043	0.782	0.651	0.609	0.921	0.895	0.814	61
119. Model 7	1138	3.187	0.818	0.517	−0.079	0.767	0.614	0.582	0.932	0.841	0.851	50
120. Model 8	1138	3.124	1.041	−0.274	−0.142	0.574	0.412	0.310	0.976	0.929	0.941	14
121. Model 9	1138	3.210	0.946	0.121	−0.056	0.629	0.467	0.392	0.975	0.895	0.934	17

Table 10. *Cont.*

Adjusted PET Model	N	Mean	a	b	MBE	RMSE	MAE	sd^2	d	R^2	sRPI	Rank
122. Model 10	1138	3.216	0.962	0.072	−0.050	0.517	0.383	0.265	0.982	0.929	0.960	4
123. Model 11	1138	3.143	1.016	−0.174	−0.123	0.589	0.434	0.331	0.977	0.919	0.946	10
124. Model 12	1120	3.232	0.896	0.273	−0.071	0.594	0.459	0.348	0.975	0.904	0.925	20
125. Model 13	1138	3.228	0.937	0.168	−0.038	0.499	0.389	0.248	0.981	0.932	0.954	7
126. Model 14	1138	3.137	0.944	0.053	−0.129	0.534	0.383	0.268	0.979	0.927	0.954	8
127. Model 15	1138	3.124	0.636	1.046	−0.142	0.989	0.814	0.958	0.904	0.756	0.742	84
Amaroussion												
FAO56-PM	1195	2.969										
113. Model 1	1194	2.908	1.037	−0.171	−0.365	0.843	0.595	0.707	0.955	0.847	0.867	42
114. Model 2	1194	2.893	1.062	−0.260	−0.379	0.843	0.592	0.705	0.962	0.855	0.866	44
115. Model 3	1193	3.057	0.833	0.583	−0.018	0.980	0.808	0.953	0.938	0.747	0.783	84
116. Model 4	1194	3.049	0.912	0.342	−0.014	0.596	0.450	0.349	0.973	0.904	0.913	21
117. Model 5	1193	3.103	0.952	0.273	−0.299	0.903	0.662	0.798	0.943	0.806	0.836	53
118. Model 6	1194	3.257	0.877	0.653	−0.043	0.579	0.466	0.253	0.976	0.934	0.907	28
119. Model 7	1194	3.182	0.744	0.972	−0.079	0.773	0.630	0.552	0.942	0.864	0.819	67
120. Model 8	1194	2.909	1.001	−0.064	−0.142	0.403	0.298	0.159	0.986	0.958	0.972	2
121. Model 9	1194	3.008	0.894	0.351	−0.056	0.515	0.392	0.264	0.981	0.928	0.928	16
122. Model 10	1194	3.017	0.926	0.267	−0.050	0.397	0.315	0.156	0.988	0.958	0.958	8
123. Model 11	1194	3.062	0.983	0.142	−0.123	0.454	0.368	0.197	0.985	0.947	0.958	9
124. Model 12	1175	3.115	0.902	0.403	−0.071	0.519	0.420	0.257	0.980	0.929	0.925	17
125. Model 13	1192	2.993	0.943	0.188	−0.038	0.426	0.336	0.181	0.986	0.950	0.959	7
126. Model 14	1194	3.099	0.939	0.311	−0.129	0.439	0.352	0.176	0.986	0.952	0.948	12
127. Model 15	1194	3.176	0.822	0.735	−0.142	0.893	0.722	0.755	0.936	0.793	0.795	77

4. Discussion

The PET estimates of the examined 112 models in this work confirm the overall good performance of the combination methods against all other groups of methods in the environment of the two Mediterranean urban green sites, i.e., in Heraklion (S. Greece) and Amaroussion (c. Greece). The general ranking of the methods for both sites indicate that the method of Wright 1996 (Equation (108)) performed the best followed by Valiantzas 2006 (2) (Equation (109)), Jensen et al. 1990 (Equation (106)), Valiantzas 2013 (6) (Equation (112)), Priestley and Taylor 1972 (Equation (85)), Valiantzas 2013 (4) (Equation (110)), Abtew 1996 (4) (Equation (86)), Valiantzas 2013 (5) (Equation (111)), Ahooghalaandari et al. 2017 (2) (Equation (99)) and Castañeda and Rao 2005 (2) (Equation (79)). The above ten are the best-performing methods for both sites, producing the best statistics and the highest sRPI scores (higher than 0.936).

The worst-performing methods are mainly mass transfer and temperature-based with limited data requirements. Specifically, the ten worst-performing models were Fitzgerald 1886 (Equation (2)) followed by Brockamp and Wenner 1963 (Equation (8)), Xu and Singh 2001 (5) (Equation (53)), Antal 1968 (Equation (50)), Xu and Singh 2001 (7) (Equation (55)), Tabari and Talaee 2011 (3) (Equation (94)), Schendel 1967 (Equation (49)), Dalton 1802 (Equation (1)), Blaney and Criddle 1950 (Equation (14)), and Smith and Stopp 1978 (Equation (21)), which received the minimum sRPI scores (lower than 0.590).

Regarding each category of empirical methods, the best-performing mass transfer method for both sites was Mahringer 1970 (Equation (10)), which ranked 45th among all 112 models (sRPI = 0.827). Respectively, the best temperature-based model was Ahooghalaandari et al. 2016 (3) (Equation (58)) ranking 27th (sRPI = 0.888), and the best radiation-based method was Priestley and Taylor 1972 (Equation (85)) ranking 5th (sRPI = 0.957). As mentioned above, the best-performing combination model for the two sites was Wright 1996 (Equation (108)), which ranked also first among all 112 models.

Specifically in Heraklion, the ten best-performing methods in descending order were Wright 1996 (Equation (108)), Valiantzas 2006 (2) (Equation (109)), Jensen et al. 1990, (Equation (106)), Ahooghalaandari et al. 2017 (2) (Equation (99)), Valiantzas 2013 (6) (Equation (112)), Valiantzas 2013 (4) (Equation (110), Valiantzas 2013 (5) (Equation (111)), Castañeda and Rao 2005 (2) (Equation (79)), Priestley and Taylor 1972 (Equation (85)), and Ahooghalaandari et al. 2017 (3) (Equation (100)), with sRPI scores higher than 0.939. Similarly, in Amaroussion, the ten best methods were Wright 1996 (Equation (108)), Priestley and Taylor 1972 (Equation (85)), Jensen et al. 1990 (Equation (106)), Valiantzas 2013 (6) (Equation (112)), Valiantzas 2006 (2) (Equation (109)), Abtew 1996 (4) (Equation (86)), Valiantzas 2013 (4) (Equation (110)), Valiantzas 2013 (5) (Equation (111)), Ahooghalaandari et al. 2017 (2) (Equation (99)) and Castañeda and Rao 2005 (2) (Equation (79)), with sRPI scores higher than 0.930.

The above-mentioned results confirm the generally increasing performance of empirical PET estimation methods with the number of input parameters [40] with the high data demanding combination methods to produce more accurate estimates. The performance of the radiation-based equations is adequate, and it ranked high among methods with limited data requirements. The better performance of the radiation methods compared to temperature-based is expected and has been confirmed also by Lang et al. [16], who applied different empirical PET models in southwestern China, suggesting Makkink's model as the best alternative. In the present work, Makking's original equation was found to perform quite well, ranking 25th among the 112 examined models with an average, for both study sites, rank score of sRPI = 0.889, whereas its modified form proposed by Castañeda and Rao 2005 (2) (Equation (79)) was ranked among the 10 best-performing methods for both examined sites and received a high sRPI score of 0.936. The good performance of the Priestley and Taylor method in this study (rank 5th/112, sRPI = 0.957) is also in line with the findings by Wei and Menzel [35], who suggested the specific method for global application.

It should be noted that the radiation-based methods requiring Rn radiation measurement are anticipated to perform better than those requiring Rs, since Rn is highly associated with the surface characteristics indicating the available energy stored in the natural surface and can be used for evapotranspiration. However, in this study, Rn is estimated from Rs [11], and thus, its effect cannot be evaluated as in the case of real in situ Rn measurements. In all cases, the best two radiation methods (included also among the 10 best out of the 112 original models) require Rn, i.e., Priestley and Taylor 1972 (Equation (85)) and Abtew 1996 (4) (Equation (86)).

The limitation of input parameters and the local calibration of the examined models appear to affect their performance in the two sites. It should be also mentioned that almost all models were established in rural areas, and thus, their application in urban environments (even in green spaces) may result in overestimations or underestimations. This is also valid for the FAO56-PM method, which is highly affected by the aerodynamic characteristics of the surface. In all cases, the energy budget and the aerodynamic characteristics of the urban green spaces are considerably different compared to the open rural areas, and the built-up urban environment highly affects the energy exchanging processes, the energy budget of the green surfaces, and the wind flow above them, resulting in a complex environment that is difficult to be modeled. Multiple radiation scattering by the built-up environment surrounding the urban green areas and shadowing, as well as the use of artificial materials covering parts of the soil, can result in decreased ET fluxes and overestimation of the applied PET models [41]. However, the estimation of PET by the empirical models remains a useful tool to assess plants' water requirements, even at the urban environment.

The general ranking of the 127 methods (112 originals and 15 adjusted) after incorporating the scores for both sites are presented in Table A5 (Appendix C). The results suggest that many of the adjusted models performed better compared to the original equations. More specifically, the mass transfer models 1 (Equation (113)) and 2 (Equation (114)) were ranked 52nd and 51st (with sRPI scores of 0.835 and 0.839), respectively, among all 127 models, whereas the best original mass transfer method (Mahringer 1970 (Equation (10), sRPI = 0.827) is ranked 57th, WMO 1966 (Equation (9)) is ranked 59th, and all others were ranked much lower compared to the adjusted mass transfer models.

Among the adjusted temperature-based models 3, 4, 5, 6 and 15 (Equations (115)–(118) and (127)), model 4 (Equation (123)), which requires only temperature data and is actually the adjustment of the Hargreaves–Samani equation, presented better performance, ranking 22nd (sRPI = 0.915) among the 127 methods and first among all temperature-based models, which was followed by the best original method of Ahooghalaandari et al. 2016 (3) (Equation (58)), which ranked 35th/127 with sRPI = 0.888. It is worth noting the good performance of the adjusted Hargreaves–Samani Model 4 (Equation (116)) which is ranked 22nd/127, as mentioned, whereas its original form Hargreaves and Samani 1985 (Equation (22)) is ranked 86th/127 (sRPI = 0.751). It should be stated, though, that at the adjusted model 4, the power of the diurnal temperature range (DTR = Tmax − Tmin) is negative and small, suggesting a minor and negative effect of DTR on PET. Since DTR is considered to be related with atmospheric cloudiness and radiation factors that control plant photosynthesis [138,146,147] and that clear sky conditions (higher DTR) can be associated with higher evapotranspiration rates [148,149], it is rather expected for there to be a positive DTR effect on PET. On the other hand, in our two sites, clear sky conditions typically persist; thus, DTR is expected to have an overall minor effect on PET.

The radiation-based adjusted models 7–14 (Equations (119)–(126)) had sufficient performance. Models 10 (Equation (122)) and 8 (Equation (120)), which are actually adjustments of the Priestley and Taylor method with (model 10) or without (model 8) interception, presented the best performances and ranked 4th and 6th, among the 127 models with sRPI values of 0.959 and 0.957, respectively. Also, models 13 (Equation (125)), 11 (Equation (123)) and 14 (Equation (126)) are among the ten best models ranking 8th, 9th and 10th, with quite similar sRPI values: 0.957, 0.952 and 0.951, respectively. It is worth noting that model 14 (Equation (126)), namely the adjustment of the original Copais (Equation (92), has significantly improved the performance of the original method, considering that the original equation is ranked 42nd/127 (sRPI = 0.871).

All adjusted models have reduced data requirements, allowing their local application in the two study sites. Nonetheless, it should be stressed that the models' performance will benefit from further adjustments, incorporating a longer timeseries of data from the two stations. Their application in other regions and cities should be performed with caution, following a proper validation. Furthermore, additional adjustments may be applied by incorporating data from new stations with different geographical characteristics. In any case, the local calibration can significantly improve the performance of the PET empirical models and is highly suggested especially in regions with a limited availability of meteorological data. In summary, the best-performing methods with rank scores (sRPI) higher than 0.950 (derived as average values from both study sites) are depicted in Table 11.

Table 11. Ranking of the best-performing PET estimation models among all 127 investigated methods with sRPI rank scores higher than 0.950.

PET Method	Category	General Form	sRPI	Rank
108. Wright 1996	Combination	PET = f (Rs, u, T, RH)	0.990	1
109. Valiantzas 2006 (2)	Combination	PET = f (Rs, u, T, RH)	0.966	2
106. Jensen et al. 1990	Combination	PET = f (Rs, u, T, RH)	0.963	3
122. Model 10 (present work)	Radiation-based	PET = f (Rs, T, RH)	0.959	4
112. Valiantzas 2013 (6)	Combination	PET = f (Rs, u, T)	0.958	5
120. Model 8 (present work)	Radiation-based	PET = f (Rs, T, RH)	0.957	6
85. Priestley and Taylor 1972	Radiation-based	PET = f (Rs, T, RH)	0.957	7
125. Model 13 (present work)	Radiation-based	PET = f (Rs, T)	0.957	8
123. Model 11 (present work)	Radiation-based	PET = f (Rs, T)	0.952	9
126. Model 14 (present work)	Radiation-based	PET = f (Rs, T, RH)	0.951	10
110. Valiantzas 2013 (4)	Combination	PET = f (Rs, u, T, RH)	0.950	11

5. Conclusions

In the present work, the performance of 112 original empirical models for the estimation of potential evapotranspiration (PET) was investigated by comparing the models' outputs with the PET estimates by the FAO56-PM standard method in two urban green sites in Greece (Heraklion, S. Greece and Amaroussion, c. Greece). Based on the general forms of the original mass transfer, temperature and radiation-based PET models, 15 adjusted equations were also produced and evaluated for application at the local level.

The results confirm that the accuracy of the model increases with the number of the input parameters included in the estimations. The combination methods produced in general more accurate PET estimates, which are followed by the radiation, temperature and mass transfer-based methods.

The combination model proposed by Wright 1996 (Equation (108) ranked 1st among the 112 original models) had the best performance, which was followed by Valiantzas 2006 (2) (Equation (109), ranked 2nd) and Jensen et al. 1990 (Equation (106), ranked 3rd), which are also combination methods. However, it is important to note that the combination methods require the same input parameters as FAO56-PM; thus, the standard method might be applied directly.

Priestley and Taylor (Equation (85), ranking 5th among the 112 original models) was the best radiation-based model and Ahooghalaandari et al. 2016 (3) (Equation (58), ranked 27th/112) was the best temperature-based one. Regardless of their high data requirements, the mass transfer methods had insufficient performance, even after adjustment. However, Mahringer 1970 (Equation (10), ranked 45th/112) was the best model of this category.

The adjusted PET models enhanced the performance of the original methods in all cases on the local level of the two study sites. The radiation-based model 10 (PET = f (Rs, T, RH)) was ranked 4th among all 127 models (112 original and 15 adjusted), presenting a high rank score. Also, models 8, 13, 11 and 14 (all radiation-based) produced accurate estimates in both sites, received high scores (>0.951) and ranked among the 10 best-performing methods. Their application in the two sites is recommended in the case of limited data availability; however, their applicability in other regions should be cautiously performed after proper validation and adjustment.

For wider application, it is proposed to test the methods in other cities around the world to evaluate the accuracy of the estimation of urban vegetation water requirements. It is essential though to underline the critical importance of the quality of measurements of the input parameters that should be obtained above irrigated, grass-covered surfaces, allowing the proper application of the FAO56-PM method. The findings of this study can be useful for the estimation of PET in Mediterranean cities and especially in areas with limited data availability. This can be particularly useful toward informed decision making for urban green infrastructure, including plant species selection, irrigation scheduling and water management as well as urban green management.

The findings from the present study, which is based on ground data, are a useful resource for determining the most appropriate method (especially at the local level) for estimating vegetation water requirements under the Mediterranean climate conditions. Based on the above principal information, using remote sensing—satellite data in the most appropriate PET methods identified in the two investigated sites, may produce more accurate local estimates. In future work, the performance of the PET methods can be evaluated by applying both satellite and ground data, and we can compare the methods performances. Further research is also required in order to validate the performance of the adjusted models by incorporating longer data series. In future work, the authors intend to investigate the performance of the original and adjusted models in other environments (urban or rural).

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The statistical analysis in this work was based on the following indices:

- Slope a, intercept b and coefficient of determination R^2 of the linear regression y = ax + b.
- Mean bias error (MBE):

$$MBE = \sum_{i=1}^{N} \frac{P_i - O_i}{N} \quad (A1)$$

- Mean absolute error (MAE):

$$MAE = \sum_{i=1}^{N} \frac{|P_i - O_i|}{N} \quad (A2)$$

- Differences distribution s_d^2 around the MBE:

$$s_d^2 = \sum_{i=1}^{N} \frac{(P_i - O_i - MBE)^2}{N-1} \quad (A3)$$

- Root mean square error (RMSE):

$$RMSE = \sqrt{\sum_{i=1}^{N} \frac{(P_i - O_i)^2}{N}} \quad (A4)$$

- Index of agreement (d):

$$d = 1 - \frac{\sum_{i=1}^{N} \frac{(P_i - O_i)^2}{N}}{\sum_{i=1}^{N} \frac{\left(\left|P_i'\right| + \left|O_i'\right|\right)^2}{N}} \quad (A5)$$

where O_i is the estimated PET by FAO56-PM, and P_i is the PET by the compared methods, $P_i' = P_i - O$ and $O_i' = O_i - O$.

The ranking of the PET methods was based on the above eight indices, and the rank scores were computed by the following equations:

$$X_i = \begin{cases} V_i\ , \text{ Type I indices } \left(R^2,\ d\right) \\ 1 - \frac{|V_i|+1}{\left|V_{i\ (max)}\right|+1}\ , \text{ Type II indices } \left(|1 - \text{slope a}|,\ |\text{offcet b}|,\ MBE,\ MAE,\ s_d^2,\ RMSE\right) \end{cases} \quad (A6)$$

$$Y_i = \frac{X_i - X_{min}}{X_{max} - X_{min}} \quad \text{(A7)}$$

$$RPI = \sum_{i=1}^{k} \frac{Y_i}{k} \quad \text{(A8)}$$

$$sRPI = \frac{RPI - RPI_{min}}{RPI_{max} - RPI_{min}} \quad \text{(A9)}$$

where V_i is each statistical index and k is the number of the statistical indices used for the RPI and sRPI estimations.

Appendix B

Daily values of the PET estimates by all used models are presented against the respective values derived by the application of the FAO56-PM model. The results are presented by category of methods.

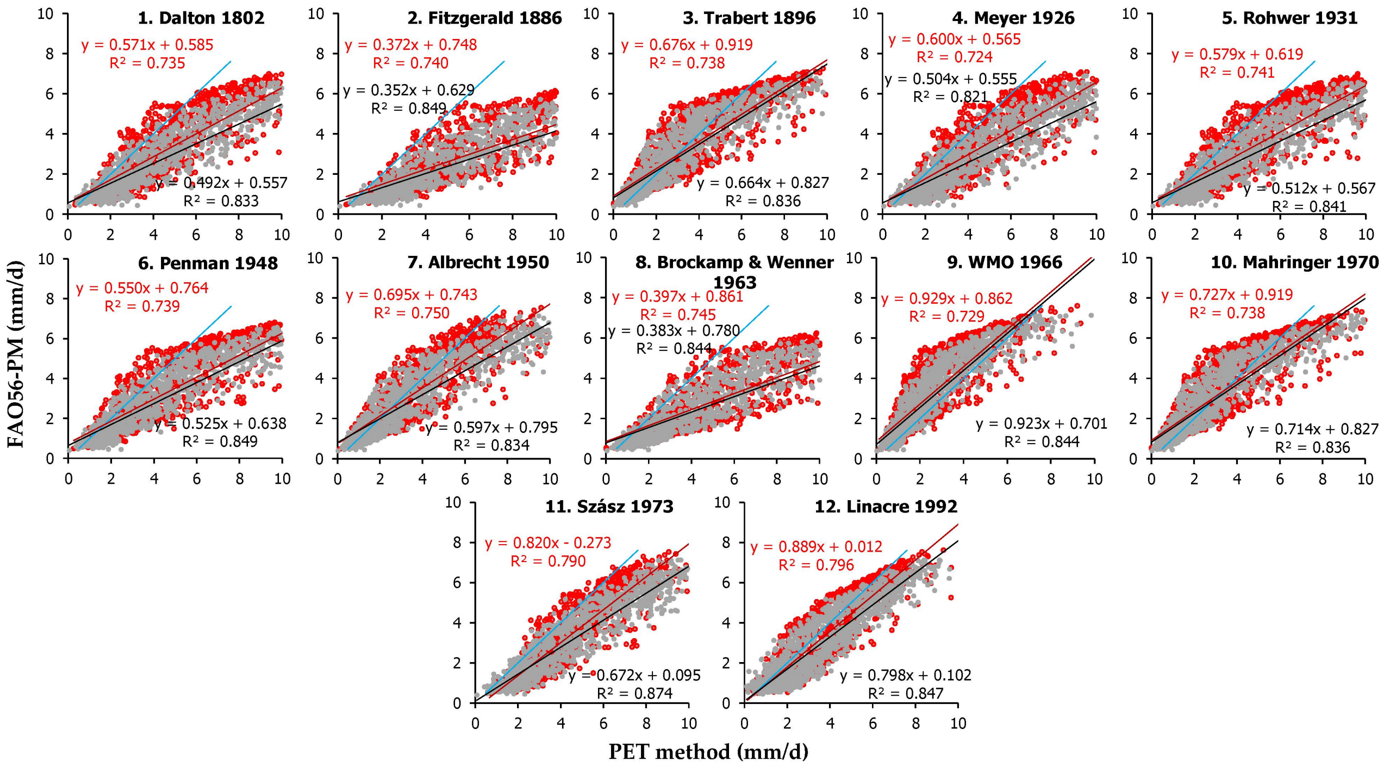

Figure A1. Correlation between daily PET values estimated by different mass transfer methods (x-axis) and the benchmark method of FAO56-PM (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

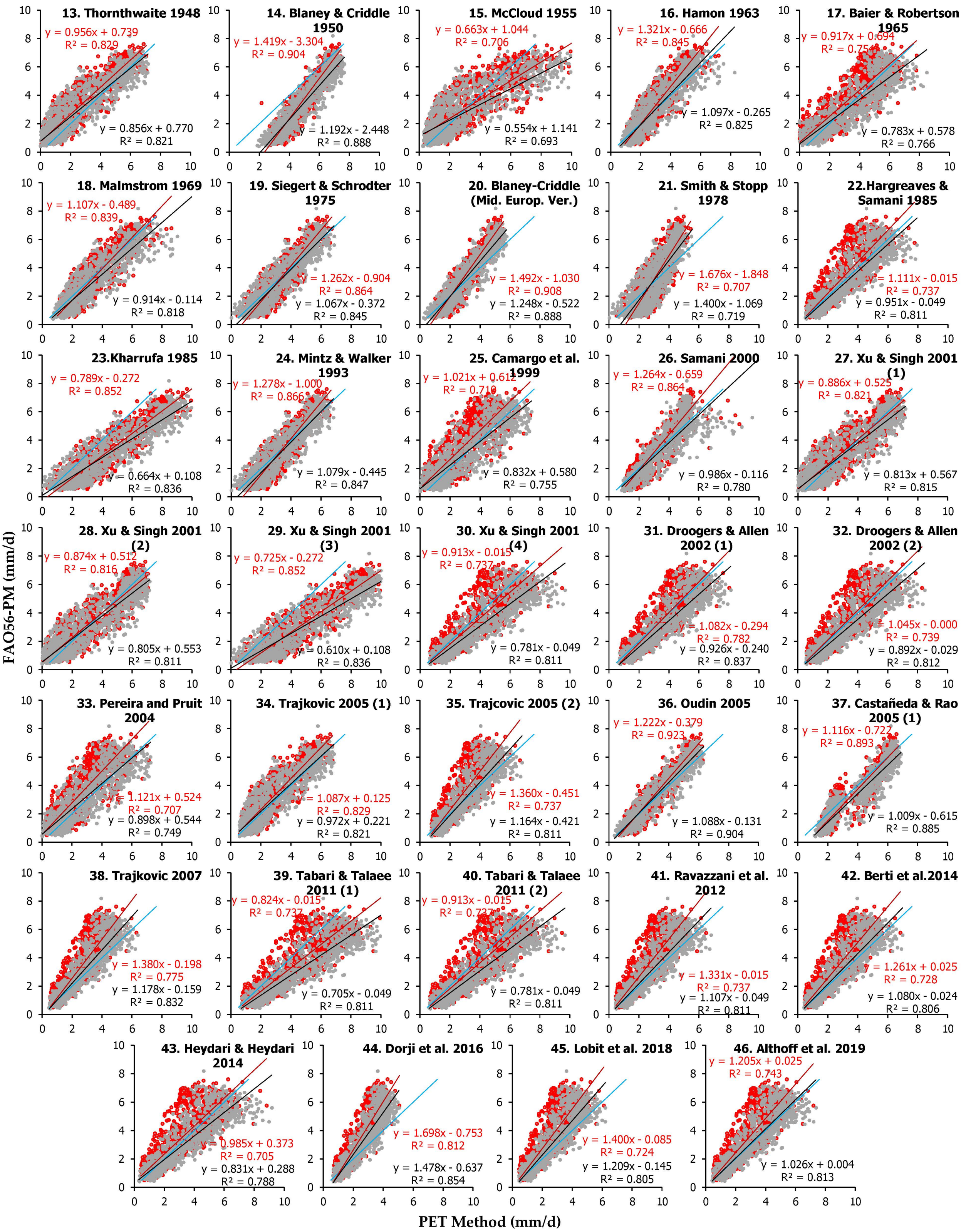

Figure A2. Correlation between daily PET values estimated by different temperature-based methods (x-axis) of the general forms PET = f (T) and the benchmark method of FAO56-PM (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

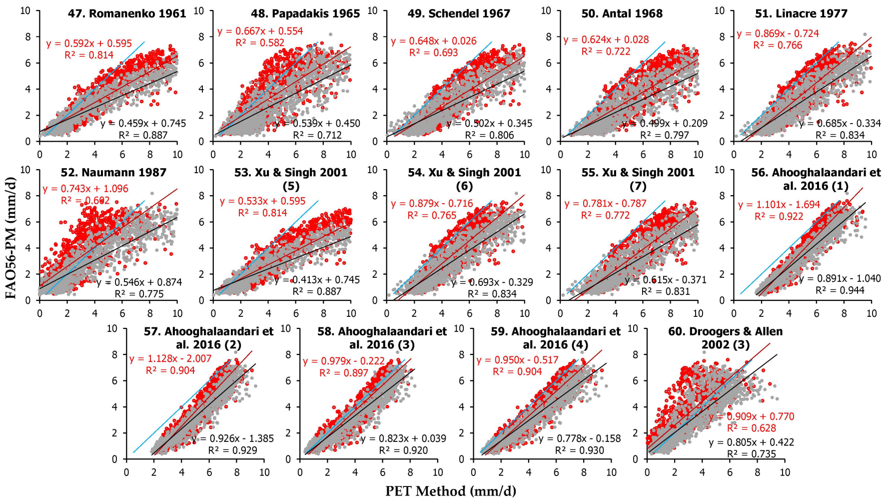

Figure A3. Correlation between daily PET values estimated by different temperature-based methods (x-axis) of the general forms PET = f (T, RH or PR) and the benchmark method of FAO56-PM (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

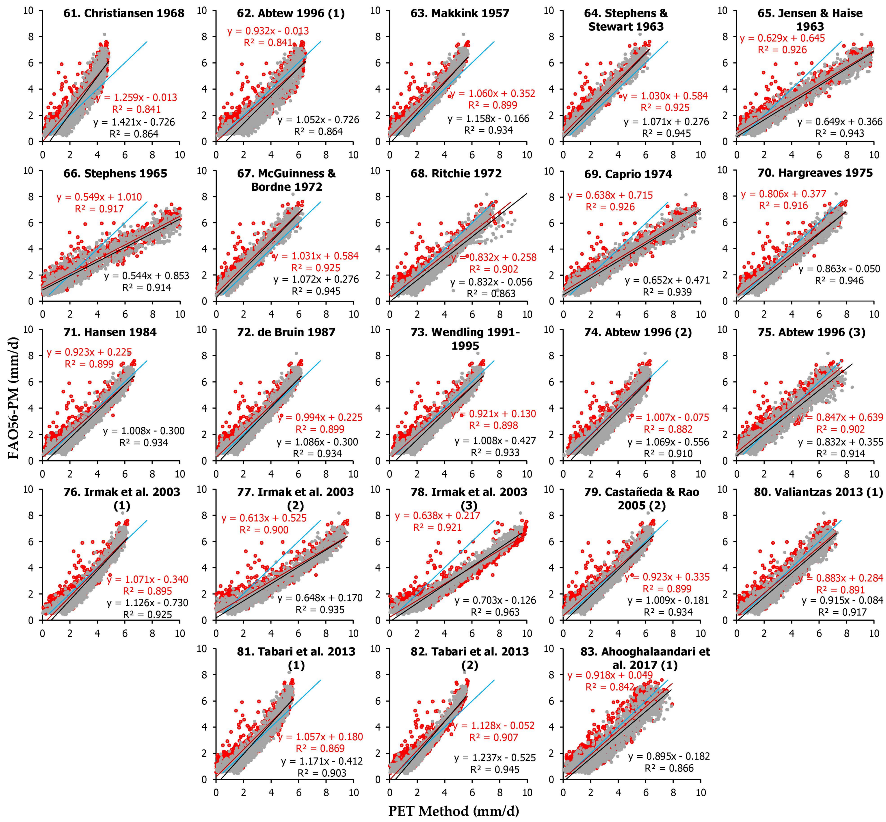

Figure A4. Correlation between daily ET values estimated by different radiation-based methods (x-axis) of the general forms PET = f (Rs) and PET = f (Rs, T) with the benchmark method of FAO56-PM (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

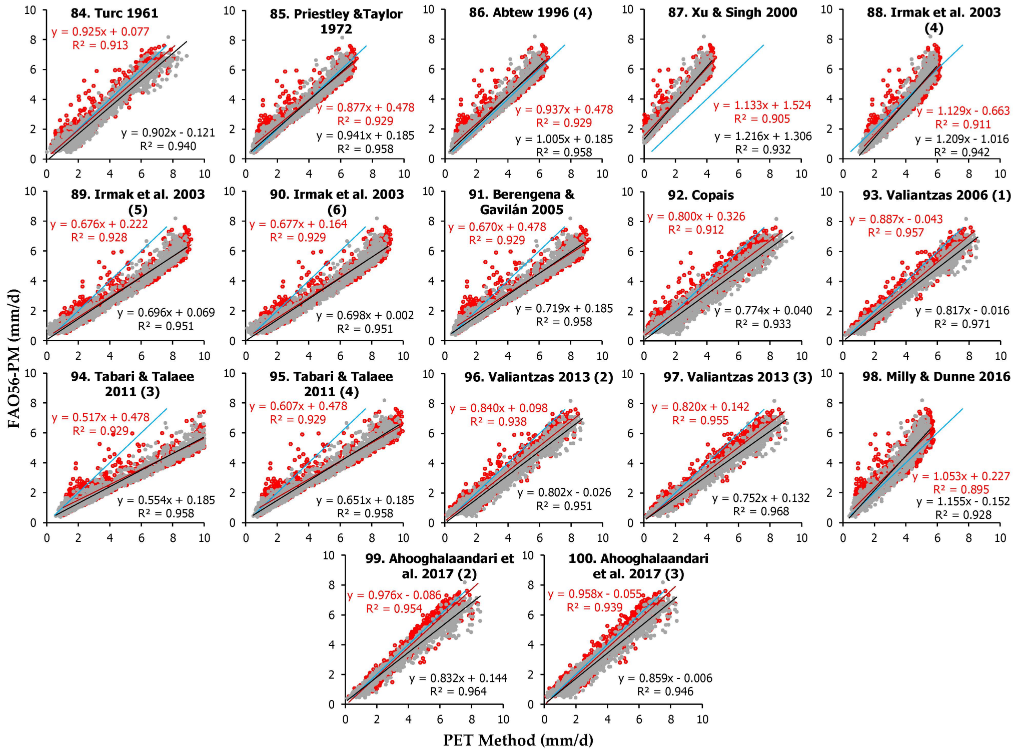

Figure A5. Correlation between daily ET values estimated by different radiation-based methods (x-axis) of the form PET = f (Rs, T, RH) with the benchmark method of FAO56-PM (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

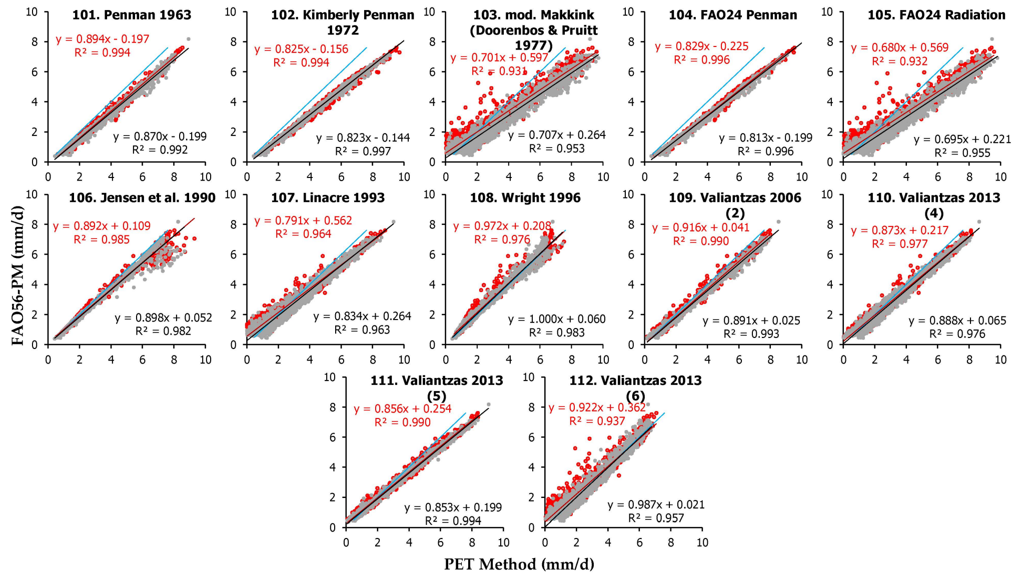

Figure A6. Correlation between daily ET values estimated by different combination methods (x-axis) and the benchmark method of FAO56-PM (y-axis) for two urban green areas in Amaroussion (gray points) and Heraklion (red points) along with the linear regression statistics. The blue line indicates the 1:1 regression.

Appendix C

Values of the statistical indices used in the present work for the ranking of the 112 PET models. The results are presented for both study sites (Heraklion and Amaroussion) and are grouped per category of methods.

The final ranking of all examined models, including the 112 original and 15 adjusted, is also presented in the last table.

Table A1. Statistical indices (mean, slope a, intercept b, and coefficient of determination R^2 of the linear regression y = ax + b, mean bias error (MBE), root mean square error (RMSE), mean absolute error (MAE), standard deviation square (sd^2), and index of agreement d) and ranking (sRPI Score and Rank) based on the optimum values of the statistical indices for the 12 mass transfer-based modes (Equations (1)–(12)) for the estimation of PET compared to the benchmark method of FAO56-PM in the two urban green sites of Heraklion and Amaroussion.

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	d	R^2	sRPI	Rank
Heraklion												
FAO56-PM	1139	3.266										
1. Dalton 1802	1139	4.692	1.287	0.491	1.429	2.126	1.528	2.477	0.810	0.735	0.603	102
2. Fitzgerald 1886	1139	6.767	1.989	0.274	3.504	4.573	3.511	8.634	0.729	0.740	0.177	112
3. Trabert 1896	1139	3.470	1.091	−0.094	0.207	1.270	0.882	1.569	0.974	0.738	0.825	47
4. Meyer 1926	1139	4.501	1.207	0.558	1.238	1.925	1.360	2.177	0.868	0.724	0.654	95
5. Rohwer 1931	1139	4.570	1.279	0.392	1.307	2.017	1.435	2.367	0.890	0.741	0.657	94
6. Penman 1948	1139	4.546	1.342	0.163	1.280	2.095	1.459	2.749	0.891	0.739	0.652	96
7. Albrecht 1950	1139	3.634	1.080	0.105	0.371	1.255	0.830	1.437	0.898	0.750	0.796	56
8. Br. and Wen. 1963	1139	6.054	1.876	−0.073	2.791	3.865	2.830	7.174	0.715	0.745	0.292	111
9. WMO 1966	1139	2.594	0.785	0.025	−0.670	1.212	0.913	1.002	0.964	0.729	0.798	55
10. Mahringer 1970	1139	3.234	1.015	−0.087	−0.029	1.158	0.834	1.332	0.919	0.738	0.827	46
11. Szász 1973	1139	4.325	0.964	1.170	1.062	1.422	1.155	0.904	0.897	0.790	0.726	74
12. Linacre 1992	1138	3.669	0.895	0.738	0.403	0.977	0.801	0.789	0.946	0.796	0.813	52
Amaroussion												
FAO56-PM	1195	2.969										
1. Dalton 1802	1195	4.904	1.694	−0.121	1.429	2.753	1.967	3.828	0.767	0.833	0.547	106
2. Fitzgerald 1886	1195	6.639	2.410	−0.514	3.504	4.942	3.674	10.937	0.764	0.849	0.189	112
3. Trabert 1896	1195	3.225	1.259	−0.514	0.207	1.197	0.786	1.368	0.981	0.836	0.817	56
4. Meyer 1926	1195	4.791	1.630	−0.049	1.238	2.617	1.862	3.531	0.830	0.821	0.597	102
5. Rohwer 1931	1195	4.690	1.642	−0.185	1.307	2.510	1.764	3.341	0.893	0.841	0.631	97
6. Penman 1948	1196	4.441	1.617	−0.361	1.280	2.285	1.537	3.065	0.906	0.849	0.651	95
7. Albrecht 1950	1195	3.647	1.398	−0.506	0.371	1.562	0.981	1.985	0.902	0.834	0.740	84
8. Br. and Wen. 1963	1195	5.716	2.203	−0.828	2.791	4.003	2.772	8.492	0.762	0.844	0.300	111
9. WMO 1966	1195	2.465	0.915	−0.259	−0.670	0.923	0.693	0.592	0.982	0.844	0.853	40
10. Mahringer 1970	1195	3.005	1.171	−0.478	−0.029	1.042	0.726	1.085	0.943	0.836	0.826	50
11. Szász 1973	1195	4.286	1.301	0.417	1.062	1.714	1.349	1.222	0.893	0.874	0.732	86
12. Linacre 1992	1187	3.620	1.062	0.446	0.403	1.076	0.903	0.761	0.957	0.847	0.831	44

Table A2. Statistical indices (mean, slope a, intercept b, and coefficient of determination R^2, of the linear regression y = ax + b, mean bias error (MBE), root mean square error (RMSE), mean absolute error (MAE), standard deviation square (sd^2), and index of agreement d) and ranking (sRPI Score and Rank) based on the optimum values of the statistical indices for the 48 temperature-based PET models (Equations (13)–(60)) compared to the benchmark method of FAO56-PM in the two urban green sites of Heraklion and Amaroussion.

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	D	R^2	sRPI	Rank
Heraklion												
FAO56-PM	1139	3.266										
13. Thornthwaite 1948	1139	2.652	0.867	−0.187	−0.611	1.015	0.794	0.631	0.926	0.829	0.832	45
14. Blaney and Criddle 1950	1139	4.637	0.637	2.548	1.374	1.582	1.400	0.637	0.789	0.904	0.585	104

Table A2. *Cont.*

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	D	R^2	sRPI	Rank
15. McCloud 1955	1139	3.362	1.065	−0.126	0.099	1.325	0.981	1.735	0.894	0.706	0.780	63
16. Hamon 1963	1139	2.988	0.640	0.887	−0.275	0.919	0.758	0.746	0.939	0.845	0.794	57
17. Baier and Robert. 1965	1042	3.025	0.823	0.170	−0.426	1.051	0.826	0.894	0.880	0.754	0.787	60
18. Malmstrom 1969	1139	3.406	0.758	0.918	0.143	0.805	0.667	0.616	0.945	0.839	0.822	49
19. Sieg. and Schrodt. 1975	1139	3.319	0.685	1.069	0.056	0.806	0.685	0.631	0.927	0.864	0.808	54
20. Bl. and Criddle (m. Eu.)	1139	2.895	0.609	0.892	−0.368	0.928	0.751	0.696	0.877	0.908	0.781	62
21. Smith and Stopp 1978	1139	3.067	0.422	1.674	−0.196	1.245	1.069	1.487	0.688	0.707	0.552	108
22. Hargr. and Samani 1985	1139	2.970	0.663	0.788	−0.293	1.050	0.776	0.986	0.807	0.737	0.706	81
23. Kharrufa 1985	1139	4.499	1.079	0.959	1.236	1.503	1.304	0.761	0.841	0.852	0.714	76
24. Mintz and Walker 1993	1139	3.356	0.677	1.126	0.093	0.815	0.697	0.639	0.955	0.866	0.814	50
25. Camargo et al. 1999	1139	2.618	0.695	0.329	−0.645	1.235	0.972	1.059	0.829	0.710	0.707	80
26. Samani 2000	1139	3.126	0.683	0.874	−0.137	0.826	0.658	0.635	0.926	0.864	0.814	51
27. Xu and Singh 2001 (1)	1139	3.114	0.926	0.068	−0.149	0.869	0.706	0.702	0.931	0.821	0.869	37
28. Xu and Singh 2001 (2)	1139	3.171	0.934	0.100	−0.092	0.877	0.718	0.731	0.950	0.816	0.876	34
29. Xu and Singh 2001 (3)	1139	4.899	1.174	1.043	1.636	1.899	1.671	0.985	0.835	0.852	0.652	97
30. Xu and Singh 2001 (4)	1139	3.619	0.807	0.959	0.356	1.058	0.881	0.984	0.946	0.737	0.767	66
31. Dr. and Allen 2002 (1)	1139	3.316	0.723	0.929	0.053	0.915	0.735	0.809	0.927	0.782	0.787	59
32. Dr. and Allen 2002 (2)	1139	3.152	0.707	0.816	−0.111	1.001	0.770	0.956	0.898	0.739	0.757	68
33. Pereira and Pruit 2004	1139	2.474	0.631	0.385	−0.790	1.340	1.057	1.096	0.818	0.707	0.678	86
34. Trajkovic 2005 (1)	1139	2.918	0.763	0.400	−0.345	0.902	0.725	0.644	0.921	0.829	0.822	48
35. Trajcovic 2005 (2)	1139	2.761	0.542	0.964	−0.502	1.209	0.893	1.148	0.823	0.737	0.669	90
36. Oudin 2005	1139	3.013	0.755	0.516	−0.251	0.709	0.578	0.392	0.935	0.923	0.869	38
37. Castañ. and Rao 2005 (1)	1139	3.602	0.800	0.960	0.339	0.743	0.610	0.426	0.943	0.893	0.841	43
38. Trajkovic 2007	1139	2.542	0.562	0.676	−0.721	1.279	0.940	1.034	0.803	0.775	0.679	85
39. Tabari and Tal. 2011 (1)	1139	4.012	0.894	1.062	0.748	1.275	1.098	1.082	0.847	0.737	0.701	83
40. Tabari and Tal. 2011 (2)	1139	3.628	0.807	0.959	0.364	1.062	0.890	0.985	0.927	0.737	0.758	67
41. Ravazzani et al. 2012	1139	2.499	0.553	0.658	−0.764	1.342	0.980	1.126	0.813	0.737	0.665	91
42. Berti et al.2014	1139	2.605	0.577	0.684	−0.658	1.275	0.924	1.105	0.812	0.728	0.672	88
43. Heydari and Heyd. 2014	1139	2.973	0.716	0.598	−0.290	1.104	0.817	1.075	0.873	0.705	0.736	71
44. Dorji et al. 2016	1139	2.403	0.478	0.806	−0.860	1.426	1.073	1.187	0.761	0.812	0.639	99
45. Lobit et al. 2018	1139	2.432	0.517	0.705	−0.832	1.421	1.043	1.221	0.744	0.724	0.617	101
46. Althoff et al. 2019	1139	2.728	0.616	0.677	−0.535	1.178	0.857	1.017	0.837	0.743	0.704	82
47. Romanenko 1961	1139	4.550	1.374	0.024	1.286	1.918	1.349	2.088	0.937	0.814	0.715	75
48. Papadakis 1965	1139	4.104	0.872	1.217	0.841	1.653	1.216	2.052	0.906	0.582	0.635	100
49. Schendel 1967	1139	5.037	1.069	1.506	1.773	2.214	1.792	1.863	0.820	0.693	0.556	107
50. Antal 1968	1139	5.232	1.158	1.411	1.969	2.392	1.983	1.972	0.851	0.722	0.550	109
51. Linacre 1977	1139	4.634	0.881	1.715	1.370	1.650	1.414	0.919	0.912	0.766	0.660	93
52. Naumann 1987	1139	2.963	0.810	0.276	−0.300	1.370	1.048	1.714	0.884	0.602	0.710	77
53. Xu and Singh 2001 (5)	1139	5.056	1.527	0.027	1.793	2.461	1.818	2.959	0.785	0.814	0.567	105
54. Xu and Singh 2001 (6)	1139	4.574	0.870	1.689	1.311	1.599	1.366	0.912	0.927	0.765	0.671	89
55. Xu and Singh 2001 (7)	1139	5.230	0.987	1.962	1.967	2.188	1.969	1.054	0.820	0.772	0.563	106
56. Ahoogh. et al. 2016 (1)	1139	4.550	0.837	1.769	1.287	1.376	1.289	0.314	0.921	0.922	0.727	72
57. Ahoogh. et al. 2016 (2)	1139	4.719	0.801	2.058	1.455	1.556	1.458	0.396	0.863	0.904	0.660	92
58. Ahoogh. et al. 2016 (3)	1139	3.609	0.916	0.569	0.346	0.717	0.562	0.379	0.966	0.897	0.889	27
59. Ahoogh. et al. 2016 (4)	1139	4.028	0.951	0.874	0.765	0.959	0.800	0.362	0.939	0.904	0.838	44
60. Dr. and Allen 2002 (3)	1132	2.808	0.691	0.493	−0.465	1.304	0.971	1.381	0.867	0.628	0.689	84
Amaroussion												
FAO56-PM	1195	2.969										
13. Thornthwaite 1948	1195	2.578	0.959	−0.278	−0.611	0.951	0.725	0.745	0.949	0.821	0.831	45
14. Blaney and Criddle 1950	1195	4.552	0.745	2.332	1.374	1.725	1.596	0.500	0.807	0.888	0.590	104
15. McCloud 1955	1195	3.311	1.251	−0.412	0.099	1.692	1.158	2.752	0.878	0.693	0.680	90
16. Hamon 1963	1195	2.958	0.752	0.714	−0.275	0.819	0.671	0.670	0.966	0.825	0.816	57
17. Baier and Robert. 1965	1044	3.432	0.978	0.235	−0.426	1.029	0.827	1.033	0.919	0.766	0.797	62
18. Malmstrom 1969	1195	3.387	0.895	0.716	0.143	0.929	0.745	0.700	0.948	0.818	0.817	55
19. Sieg. and Schrodt. 1975	1194	3.148	0.793	0.779	0.056	0.783	0.656	0.587	0.952	0.845	0.829	47
20. Bl. and Criddle (m. Eu.)	1195	2.812	0.711	0.685	−0.368	0.761	0.611	0.550	0.939	0.888	0.830	46

Table A2. *Cont.*

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	D	R^2	sRPI	Rank
21. Smith and Stopp 1978	1194	2.902	0.514	1.360	−0.196	1.119	0.959	1.245	0.811	0.719	0.628	98
22. Hargr. and Samani 1985	1195	3.190	0.853	0.643	−0.293	0.868	0.690	0.712	0.909	0.811	0.796	63
23. Kharrufa 1985	1194	4.329	1.260	0.570	1.236	1.785	1.484	1.387	0.851	0.836	0.679	91
24. Mintz and Walker 1993	1194	3.184	0.785	0.835	0.093	0.793	0.668	0.592	0.969	0.847	0.831	43
25. Camargo et al. 1999	1195	2.890	0.907	0.176	−0.645	1.013	0.808	1.018	0.920	0.755	0.783	70
26. Samani 2000	1195	3.149	0.791	0.781	−0.137	0.919	0.669	0.820	0.936	0.780	0.785	69
27. Xu and Singh 2001 (1)	1195	2.974	1.002	−0.022	−0.149	0.921	0.737	0.849	0.939	0.815	0.857	37
28. Xu and Singh 2001 (2)	1195	3.023	1.008	0.010	−0.092	0.938	0.753	0.880	0.951	0.811	0.861	36
29. Xu and Singh 2001 (3)	1194	4.714	1.371	0.620	1.636	2.195	1.832	1.853	0.828	0.836	0.613	100
30. Xu and Singh 2001 (4)	1195	3.886	1.038	0.783	0.356	1.320	1.087	0.942	0.945	0.811	0.781	72
31. Dr. and Allen 2002 (1)	1195	3.487	0.903	0.783	0.053	0.939	0.787	0.637	0.952	0.837	0.826	51
32. Dr. and Allen 2002 (2)	1195	3.384	0.910	0.659	−0.111	0.951	0.776	0.752	0.941	0.812	0.814	59
33. Pereira and Pruit 2004	1195	2.728	0.834	0.225	−0.790	1.022	0.811	0.973	0.926	0.749	0.768	78
34. Trajkovic 2005 (1)	1195	2.852	0.844	0.321	−0.345	0.837	0.666	0.681	0.946	0.821	0.832	42
35. Trajcovic 2005 (2)	1195	2.940	0.697	0.845	−0.502	0.881	0.670	0.774	0.924	0.811	0.769	77
36. Oudin 2005	1195	2.878	0.831	0.382	−0.251	0.642	0.501	0.399	0.957	0.904	0.885	27
37. Castañ. and Rao 2005 (1)	1195	3.581	0.877	0.949	0.339	0.888	0.743	0.448	0.934	0.885	0.822	53
38. Trajkovic 2007	1195	2.685	0.706	0.559	−0.721	0.899	0.634	0.710	0.923	0.832	0.788	66
39. Tabari and Tal. 2011 (1)	1195	4.308	1.149	0.866	0.748	1.715	1.423	1.231	0.822	0.811	0.673	92
40. Tabari and Tal. 2011 (2)	1195	3.895	1.038	0.783	0.364	1.323	1.096	0.951	0.933	0.811	0.776	74
41. Ravazzani et al. 2012	1195	2.758	0.732	0.552	−0.764	0.898	0.640	0.748	0.945	0.811	0.789	65
42. Berti et al.2014	1195	2.805	0.746	0.557	−0.658	0.890	0.642	0.755	0.921	0.806	0.781	71
43. Heydari and Heyd. 2014	1195	3.261	0.949	0.410	−0.290	0.994	0.776	0.922	0.925	0.788	0.805	60
44. Dorji et al. 2016	1195	2.475	0.578	0.724	−0.860	1.081	0.785	0.889	0.889	0.854	0.744	83
45. Lobit et al. 2018	1195	2.611	0.666	0.598	−0.832	0.993	0.696	0.832	0.871	0.805	0.738	85
46. Althoff et al. 2019	1195	2.926	0.792	0.537	−0.535	0.850	0.636	0.718	0.926	0.813	0.798	61
47. Romanenko 1961	1195	4.883	1.933	−0.891	1.286	2.904	1.977	4.911	0.914	0.887	0.559	105
48. Papadakis 1965	1195	4.711	1.321	0.753	0.841	2.424	1.821	2.971	0.900	0.712	0.600	101
49. Schendel 1967	1194	5.263	1.604	0.460	1.773	2.946	2.319	3.601	0.843	0.806	0.531	107
50. Antal 1968	1195	5.566	1.597	0.786	1.969	3.197	2.604	3.679	0.852	0.797	0.489	109
51. Linacre 1977	1195	4.859	1.217	1.206	1.370	2.169	1.899	1.281	0.914	0.834	0.646	96
52. Naumann 1987	1195	3.877	1.418	−0.376	−0.300	1.882	1.238	2.793	0.908	0.775	0.699	88
53. Xu and Singh 2001 (5)	1195	5.426	2.147	−0.990	1.793	3.573	2.492	6.936	0.802	0.887	0.407	110
54. Xu and Singh 2001 (6)	1195	4.798	1.203	1.184	1.311	2.104	1.839	1.237	0.931	0.834	0.662	94
55. Xu and Singh 2001 (7)	1195	5.470	1.351	1.418	1.967	2.806	2.506	1.834	0.830	0.831	0.518	108
56. Ahoogh. et al. 2016 (1)	1195	4.542	1.059	1.353	1.287	1.624	1.575	0.302	0.933	0.944	0.746	82
57. Ahoogh. et al. 2016 (2)	1195	4.749	1.004	1.724	1.455	1.826	1.782	0.328	0.877	0.929	0.682	89
58. Ahoogh. et al. 2016 (3)	1195	3.607	1.118	0.240	0.346	0.917	0.719	0.493	0.964	0.920	0.887	26
59. Ahoogh. et al. 2016 (4)	1195	4.068	1.196	0.472	0.765	1.299	1.106	0.581	0.929	0.930	0.815	58
60. Dr. and Allen 2002 (3)	1194	3.213	0.913	0.452	−0.465	1.096	0.863	1.166	0.941	0.735	0.770	76

Table A3. Statistical indices (mean, slope a, intercept b, and coefficient of determination R^2, of the linear regression y = ax + b, mean bias error (MBE), root mean square error (RMSE), mean absolute error (MAE), standard deviation square (sd^2), and index of agreement d) and ranking (sRPI Score and Rank) based on the optimum values of the statistical indices for the 40 radiation-based models (Equations (61)–(100)) for the estimation of PET compared to the benchmark method of FAO56-PM in the two urban green sites of Heraklion and Amaroussion.

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	D	R^2	sRPI	Rank
Heraklion												
FAO56-PM	1139	3.266										
61. Christiansen 1968	1139	2.657	0.668	0.423	−0.607	1.094	0.880	0.711	0.884	0.841	0.775	64
62. Abtew 1996 (1)	1139	3.570	0.903	0.571	0.307	0.845	0.706	0.598	0.935	0.841	0.846	42
63. Makkink 1957	1138	2.806	0.849	−0.021	−0.460	0.835	0.673	0.380	0.944	0.899	0.886	29

Table A3. *Cont.*

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	D	R^2	sRPI	Rank
64. Stephens and Stewart 1963	1139	2.659	0.898	−0.329	−0.605	0.877	0.742	0.279	0.943	0.925	0.878	33
65. Jensen and Haise 1963	1139	4.219	1.471	−0.640	0.956	1.519	1.260	1.444	0.897	0.926	0.727	73
66. Stephens 1965	1135	4.181	1.670	−1.342	0.909	1.826	1.428	2.556	0.921	0.917	0.644	98
67. McGuinness and Bordne 1972	1139	2.659	0.898	−0.329	−0.604	0.880	0.747	0.279	0.950	0.925	0.880	31
68. Ritchie 1972	1139	3.671	1.084	0.076	0.408	0.820	0.716	0.494	0.958	0.902	0.898	24
69. Caprio 1974	1139	4.053	1.450	−0.740	0.790	1.395	1.149	1.356	0.927	0.926	0.753	70
70. Hargreaves 1975	1139	3.641	1.137	−0.129	0.378	0.812	0.716	0.501	0.976	0.916	0.902	22
71. Hansen 1984	1139	3.353	0.974	0.112	0.090	0.672	0.554	0.393	0.975	0.899	0.934	12
72. de Bruin 1987	1139	3.119	0.905	0.104	−0.144	0.687	0.546	0.370	0.976	0.899	0.924	14
73. Wendling 1991–1995	1139	3.466	0.975	0.220	0.203	0.692	0.582	0.399	0.967	0.898	0.919	17
74. Abtew 1996 (2)	1139	3.380	0.876	0.457	0.117	0.705	0.590	0.434	0.965	0.882	0.891	26
75. Abtew 1996 (3)	1139	3.165	1.065	−0.376	−0.099	0.747	0.606	0.469	0.967	0.902	0.907	19
76. Irmak et al. 2003 (1)	1138	3.433	0.836	0.639	0.168	0.688	0.586	0.401	0.965	0.895	0.880	32
77. Irmak et al. 2003 (2)	1047	4.846	1.467	−0.292	1.395	1.851	1.641	1.612	0.854	0.900	0.676	87
78. Irmak et al. 2003 (3)	1123	4.899	1.444	0.071	1.603	1.945	1.730	1.366	0.910	0.921	0.709	78
79. Castañeda and Rao 2005 (2)	1138	3.243	0.974	−0.007	−0.022	0.683	0.553	0.394	0.979	0.899	0.943	8
80. Valiantzas 2013 (1)	1137	3.448	1.009	0.082	0.182	0.734	0.634	0.460	0.966	0.891	0.922	15
81. Tabari et al. 2013 (1)	1133	3.002	0.823	0.234	−0.275	0.821	0.677	0.488	0.951	0.869	0.872	35
82. Tabari et al. 2013 (2)	1134	3.021	0.804	0.317	−0.252	0.747	0.602	0.386	0.951	0.907	0.884	30
83. Ahooghalaan. et al. 2017 (1)	1137	3.576	0.917	0.508	0.311	0.854	0.755	0.605	0.941	0.842	0.851	41
84. Turc 1961	1139	3.517	0.986	0.225	0.253	0.668	0.569	0.346	0.971	0.913	0.926	13
85. Priestley and Taylor 1972	1139	3.249	1.058	−0.279	−0.014	0.639	0.499	0.332	0.986	0.929	0.941	9
86. Abtew 1996 (4)	1139	3.048	0.991	−0.261	−0.215	0.660	0.486	0.281	0.969	0.929	0.935	11
87. Xu and Singh 2000	839	2.262	0.799	−1.012	−1.705	1.923	1.912	0.331	0.691	0.905	0.603	103
88. Irmak et al. 2003 (4)	1139	3.556	0.807	0.845	0.292	0.700	0.612	0.373	0.955	0.911	0.862	39
89. Irmak et al. 2003 (5)	1139	4.581	1.374	0.018	1.318	1.630	1.407	1.047	0.932	0.928	0.769	65
90. Irmak et al. 2003 (6)	1139	4.655	1.371	0.100	1.391	1.682	1.465	1.033	0.922	0.929	0.755	69
91. Berengena and Gavilán 2005	1139	4.237	1.386	−0.365	0.974	1.400	1.165	1.086	0.944	0.929	0.783	61
92. Copais	1139	3.755	1.140	−0.046	0.492	0.883	0.757	0.537	0.958	0.912	0.888	28
93. Valiantzas 2006 (1)	1139	3.809	1.079	0.207	0.546	0.714	0.630	0.219	0.974	0.957	0.921	16
94. Tabari and Talaee 2011 (3)	1139	5.474	1.797	−0.474	2.211	2.799	2.276	3.226	0.775	0.929	0.495	110
95. Tabari and Talaee 2011 (4)	1139	4.669	1.529	−0.403	1.405	1.872	1.536	1.679	0.937	0.929	0.708	79
96. Valiantzas 2013 (2)	1139	3.851	1.117	0.123	0.588	0.828	0.741	0.354	0.965	0.938	0.900	23
97. Valiantzas 2013 (3)	1139	3.893	1.165	0.006	0.630	0.845	0.720	0.339	0.966	0.955	0.904	20
98. Milly and Dunne 2016	1139	2.969	0.850	0.109	−0.294	0.787	0.610	0.397	0.974	0.895	0.903	21
99. Ahooghalaan. et al. 2017 (2)	1139	3.518	0.977	0.243	0.255	0.534	0.416	0.178	0.984	0.954	0.955	4
100. Ahooghalaan. et al. 2017 (3)	1139	3.552	0.980	0.266	0.289	0.598	0.493	0.237	0.976	0.939	0.939	10
Amaroussion												
FAO56-PM	1195	2.969										
61. Christiansen 1968	1195	2.650	0.608	0.795	−0.607	0.976	0.784	0.819	0.907	0.864	0.768	79
62. Abtew 1996 (1)	1195	3.562	0.822	1.073	0.307	0.920	0.779	0.553	0.903	0.864	0.786	68
63. Makkink 1957	1193	2.760	0.807	0.311	−0.460	0.650	0.530	0.356	0.959	0.934	0.892	25
64. Stephens and Stewart 1963	1195	2.566	0.883	−0.106	−0.605	0.688	0.574	0.270	0.959	0.945	0.907	20
65. Jensen and Haise 1963	1195	4.063	1.452	−0.301	0.956	1.531	1.218	1.262	0.891	0.943	0.766	80
66. Stephens 1965	1155	4.073	1.681	−1.087	0.909	1.909	1.428	2.685	0.915	0.914	0.669	93
67. McGuinness and Bordne 1972	1195	2.567	0.882	−0.106	−0.604	0.692	0.579	0.273	0.966	0.945	0.910	18
68. Ritchie 1972	1195	3.691	1.037	0.558	0.408	1.062	0.810	0.685	0.925	0.863	0.825	52
69. Caprio 1974	1195	3.886	1.439	−0.443	0.790	1.410	1.103	1.248	0.925	0.939	0.786	67
70. Hargreaves 1975	1195	3.553	1.096	0.244	0.378	0.787	0.694	0.343	0.977	0.946	0.910	17
71. Hansen 1984	1195	3.299	0.927	0.491	0.090	0.609	0.522	0.301	0.977	0.934	0.916	12
72. de Bruin 1987	1195	3.068	0.860	0.456	−0.144	0.566	0.469	0.323	0.984	0.934	0.916	13
73. Wendling 1991–1995	1195	3.429	0.926	0.621	0.203	0.681	0.591	0.307	0.963	0.933	0.894	24
74. Abtew 1996 (2)	1195	3.357	0.851	0.771	0.117	0.714	0.610	0.406	0.961	0.910	0.869	32
75. Abtew 1996 (3)	1195	3.201	1.098	−0.121	−0.099	0.733	0.608	0.511	0.967	0.914	0.911	16
76. Irmak et al. 2003 (1)	1192	3.352	0.822	0.846	0.168	0.690	0.595	0.380	0.959	0.925	0.867	33
77. Irmak et al. 2003 (2)	1103	4.661	1.442	0.055	1.395	1.832	1.633	1.269	0.852	0.935	0.720	87
78. Irmak et al. 2003 (3)	1180	4.507	1.370	0.339	1.603	1.707	1.555	0.825	0.925	0.963	0.758	81
79. Castañeda and Rao 2005 (2)	1194	3.188	0.926	0.373	−0.022	0.572	0.486	0.308	0.984	0.934	0.930	10
80. Valiantzas 2013 (1)	1185	3.419	1.002	0.361	0.182	0.727	0.634	0.399	0.964	0.917	0.905	21
81. Tabari et al. 2013 (1)	1183	2.974	0.772	0.599	−0.275	0.702	0.590	0.490	0.961	0.903	0.863	35
82. Tabari et al. 2013 (2)	1190	2.898	0.764	0.556	−0.252	0.644	0.531	0.398	0.956	0.945	0.885	28
83. Ahooghalaan. et al. 2017 (1)	1186	3.606	0.967	0.651	0.311	0.950	0.836	0.601	0.926	0.866	0.828	48
84. Turc 1961	1194	3.497	1.042	0.332	0.253	0.734	0.629	0.334	0.969	0.940	0.912	15
85. Priestley and Taylor 1972	1195	3.027	1.018	−0.065	−0.014	0.486	0.375	0.241	0.992	0.958	0.972	2
86. Abtew 1996 (4)	1195	2.841	0.954	−0.061	−0.215	0.513	0.374	0.229	0.979	0.958	0.956	6

Table A3. *Cont.*

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	D	R^2	sRPI	Rank
87. Xu and Singh 2000	861	2.116	0.767	−0.865	−1.705	1.843	1.840	0.379	0.702	0.932	0.621	99
88. Irmak et al. 2003 (4)	1195	3.368	0.779	0.983	0.292	0.701	0.640	0.390	0.952	0.942	0.854	39
89. Irmak et al. 2003 (5)	1193	4.244	1.366	0.110	1.318	1.531	1.325	0.912	0.933	0.951	0.793	64
90. Irmak et al. 2003 (6)	1193	4.330	1.362	0.208	1.391	1.595	1.399	0.902	0.926	0.951	0.777	73
91. Berengena and Gavilán 2005	1195	3.947	1.333	−0.085	0.974	1.256	1.035	0.765	0.951	0.958	0.839	41
92. Copais	1195	3.859	1.205	0.206	0.492	1.128	0.975	0.614	0.940	0.933	0.854	38
93. Valiantzas 2006 (1)	1195	3.728	1.188	0.125	0.546	0.908	0.778	0.363	0.966	0.971	0.901	23
94. Tabari and Talaee 2011 (3)	1195	5.100	1.729	−0.110	2.211	2.588	2.144	2.483	0.788	0.958	0.591	103
95. Tabari and Talaee 2011 (4)	1195	4.350	1.471	−0.093	1.405	1.710	1.413	1.230	0.942	0.958	0.775	75
96. Valiantzas 2013 (2)	1194	3.815	1.186	0.213	0.588	1.027	0.903	0.473	0.955	0.951	0.873	31
97. Valiantzas 2013 (3)	1195	3.852	1.287	−0.048	0.630	1.108	0.913	0.586	0.952	0.968	0.873	30
98. Milly and Dunne 2016	1195	2.783	0.804	0.316	−0.294	0.687	0.506	0.408	0.977	0.928	0.902	22
99. Ahooghalaan. et al. 2017 (2)	1195	3.474	1.158	−0.045	0.255	0.731	0.562	0.361	0.978	0.964	0.933	9
100. Ahooghalaan. et al. 2017 (3)	1194	3.548	1.102	0.192	0.289	0.785	0.663	0.377	0.970	0.946	0.913	14

Table A4. Statistical indices (mean, slope a, intercept b, and coefficient of determination R^2, of the linear regression y = ax + b, mean bias error (MBE), root mean square error (RMSE), mean absolute error (MAE), standard deviation square (sd^2), and index of agreement d) and ranking (sRPI Score and Rank) based on the optimum values of the statistical indices for the 12 combination models (Equations (101)–(112)) for the estimation of PET compared to the benchmark method of FAO56-PM in the two urban green sites of Heraklion and Amaroussion.

PET Method	N	Mean	a	b	MBE	RMSE	MAE	sd^2	D	R^2	sRPI	Rank
Heraklion												
FAO56-PM	1139	3.266										
101. Penman 1963	1139	3.959	1.112	0.240	0.695	0.727	0.695	0.079	0.969	0.994	0.918	18
102. Kimberly Penman 1972	1139	4.233	1.205	0.212	0.970	1.025	0.970	0.192	0.952	0.994	0.869	36
103. mod. Makkink (Door. and Pruitt 1977)	1127	3.932	1.327	−0.524	0.642	1.120	0.988	0.868	0.941	0.931	0.813	53
104. FAO24 Penman	1139	4.298	1.201	0.288	1.035	1.073	1.035	0.178	0.953	0.996	0.861	40
105. FAO24 Radiation	1127	4.094	1.370	−0.507	0.804	1.260	1.119	0.997	0.942	0.932	0.792	58
106. Jensen et al. 1990	1139	3.629	1.104	−0.067	0.365	0.524	0.377	0.116	0.989	0.985	0.963	3
107. Linacre 1993	1095	3.636	1.219	−0.558	0.276	0.704	0.641	0.375	0.975	0.964	0.896	25
108. Wright 1996	1139	3.239	1.005	−0.134	−0.024	0.446	0.315	0.099	0.989	0.976	0.987	1
109. Valiantzas 2006 (2)	1139	3.615	1.081	−0.008	0.352	0.479	0.411	0.078	0.986	0.990	0.970	2
110. Valiantzas 2013 (4)	1138	3.590	1.120	−0.164	0.324	0.553	0.499	0.167	0.983	0.977	0.947	6
111. Valiantzas 2013 (5)	1139	3.612	1.156	−0.257	0.349	0.548	0.446	0.149	0.985	0.990	0.943	7
112. Valiantzas 2013 (6)	1136	3.251	1.016	−0.170	−0.017	0.604	0.488	0.263	0.979	0.937	0.954	5
Amaroussion												
FAO56-PM	1195	2.969										
101. Penman 1963	1195	3.722	1.140	0.255	0.695	0.802	0.755	0.200	0.968	0.992	0.908	19
102. Kimberly Penman 1972	1195	3.868	1.212	0.187	0.970	0.965	0.901	0.272	0.958	0.997	0.883	29
103. mod. Makkink (Door. and Pruitt 1977)	1181	3.951	1.349	−0.176	0.642	1.266	1.092	0.854	0.924	0.953	0.828	49
104. FAO24 Penman	1195	3.982	1.225	0.260	1.035	1.075	1.015	0.300	0.953	0.996	0.865	34
105. FAO24 Radiation	1183	4.076	1.375	−0.126	0.804	1.381	1.204	0.922	0.934	0.955	0.819	54
106. Jensen et al. 1990	1195	3.336	1.093	0.003	0.365	0.529	0.370	0.209	0.988	0.982	0.963	3
107. Linacre 1993	1152	3.436	1.155	−0.181	0.276	0.668	0.608	0.369	0.976	0.963	0.924	11
108. Wright 1996	1195	2.998	0.984	−0.010	−0.024	0.393	0.264	0.159	0.991	0.983	0.992	1
109. Valiantzas 2006 (2)	1195	3.391	1.114	−0.006	0.352	0.528	0.443	0.176	0.983	0.993	0.962	5
110. Valiantzas 2013 (4)	1194	3.361	1.099	0.007	0.324	0.570	0.513	0.244	0.982	0.976	0.952	7
111. Valiantzas 2013 (5)	1195	3.338	1.165	−0.213	0.349	0.546	0.429	0.229	0.984	0.994	0.947	8
112. Valiantzas 2013 (6)	1185	3.098	0.969	0.110	−0.017	0.502	0.422	0.260	0.985	0.957	0.962	4

Table A5. Ranking of all 127 models (112 original and 15 adjusted).

PET Method	Category	Form	sRPI	Rank
108. Wright 1996	Combination	PET = f (Rs, u, T, RH)	0.990	1
109. Valiantzas 2006 (2)	Combination	PET = f (Rs, u, T, RH)	0.966	2
106. Jensen et al. 1990	Combination	PET = f (Rs, u, T, RH)	0.963	3
122. Model 10	Radiation-based	PET = f (Rs, T, RH)	0.959	4
112. Valiantzas 2013 (6)	Combination	PET = f (Rs, u, T)	0.958	5
120. Model 8	Radiation-based	PET =f (Rs, T, RH)	0.957	6
85. Priestley and Taylor 1972	Radiation-based	PET = f (Rs, T, RH)	0.957	7
125. Model 13	Radiation-based	PET = f (Rs, T)	0.957	8
123. Model 11	Radiation-based	PET = f (Rs, T)	0.952	9
126. Model 14	Radiation-based	PET = f (Rs, T, RH)	0.951	10
110. Valiantzas 2013 (4)	Combination	PET = f (Rs, u, T, RH)	0.950	11
86. Abtew 1996 (4)	Radiation-based	PET = f (Rs, T, RH)	0.945	12
111. Valiantzas 2013 (5)	Combination	PET = f (Rs, u, T, RH)	0.945	13
99. Ahooghalaandari et al. 2017 (2)	Radiation-based	PET = f (Rs, T, RH)	0.944	14
79. Castañeda and Rao 2005 (2)	Radiation-based	PET = f (Rs, T)	0.936	15
121. Model 9	Radiation-based	PET = f (Rs, T)	0.931	16
100. Ahooghalaandari et al. 2017 (3)	Radiation-based	PET = f (Rs, T, RH)	0.926	17
124. Model 12	Radiation-based	PET = f (Rs, T)	0.925	18
71. Hansen 1984	Radiation-based	PET = f (Rs, T)	0.925	19
72. de Bruin 1987	Radiation-based	PET = f (Rs, T)	0.920	20
84. Turc 1961	Radiation-based	PET = f (Rs, T, RH)	0.919	21
116. Model 4	Temperature-based	PET = f (T)	0.915	22
80. Valiantzas 2013 (1)	Radiation-based	PET = f (Rs, T)	0.913	23
101. Penman 1963	Combination	PET = f (Rs, u, T, RH)	0.913	24
93. Valiantzas 2006 (1)	Radiation-based	PET = f (Rs, T, RH)	0.911	25
107. Linacre 1993	Combination	PET = f (Rs, u, T, RH)	0.910	26
75. Abtew 1996 (3)	Radiation-based	PET = f (Rs, T)	0.909	27
73. Wendling 1991–1995	Radiation-based	PET = f (Rs, T)	0.906	28
70. Hargreaves 1975	Radiation-based	PET = f (Rs, T)	0.906	29
98. Milly and Dunne 2016	Radiation-based	PET = f (Rs, T, RH)	0.902	30
67. McGuinness and Bordne 1972	Radiation-based	PET = f (Rs, T)	0.895	31
64. Stephens and Stewart 1963	Radiation-based	PET = f (Rs, T)	0.892	32
63. Makkink 1957	Radiation-based	PET = f (Rs, T)	0.889	33
97. Valiantzas 2013 (3)	Radiation-based	PET = f (Rs, T, RH)	0.888	34
58. Ahooghalaandari et al. 2016 (3)	Temperature-based	PET = f (T, RH)	0.888	35
96. Valiantzas 2013 (2)	Radiation-based	PET = f (Rs, T, RH)	0.886	36
82. Tabari et al. 2013 (2)	Radiation-based	PET = f (Rs, T)	0.884	37
74. Abtew 1996 (2)	Radiation-based	PET = f (Rs, T)	0.880	38
36. Oudin 2005	Temperature-based	PET = f (T)	0.877	39
102. Kimberly Penman 1972	Combination	PET = f (Rs, u, T, RH)	0.876	40
76. Irmak et al. 2003 (1)	Radiation-based	PET = f (Rs, T)	0.874	41
92. Copais	Radiation-based	PET = f (Rs, T, RH)	0.871	42
28. Xu and Singh 2001 (2)	Temperature-based	PET = f (T)	0.869	43
81. Tabari et al. 2013 (1)	Radiation-based	PET = f (Rs, T)	0.867	44
104. FAO24 Penman	Combination	PET = f (Rs, u, T, RH)	0.863	45
27. Xu and Singh 2001 (1)	Temperature-based	PET = f (T)	0.863	46
68. Ritchie 1972	Radiation-based	PET = f (Rs, T)	0.861	47
118. Model 6	Temperature-based	PET =f (T,RH)	0.860	48
88. Irmak et al. 2003 (4)	Radiation-based	PET = f (Rs, T, RH)	0.858	49
83. Ahooghalaandari et al. 2017 (1)	Radiation-based	PET = f (Rs, T)	0.839	50
114. Model 2	Mass transfer-based	PET = f (u,T,RH)	0.839	51
113. Model 1	Mass transfer-based	PET = f (u,T,RH)	0.835	52
119. Model 7	Radiation-based	PET = f (Rs)	0.835	53
13. Thornthwaite 1948	Temperature-based	PET = f (T)	0.831	54
37. Castañeda and Rao 2005 (1)	Temperature-based	PET = f (T)	0.831	55
34. Trajkovic 2005 (1)	Temperature-based	PET = f (T)	0.827	56
10. Mahringer 1970	Mass transfer-based	PET = f (u, T, RH)	0.827	57

Table A5. *Cont.*

PET Method	Category	Form	sRPI	Rank
59. Ahooghalaandari et al. 2016 (4)	Temperature-based	PET = f (T, RH)	0.826	58
9. WMO 1966	Mass transfer-based	PET = f (u, T, RH)	0.826	59
24. Mintz and Walker 1993	Temperature-based	PET = f (T)	0.823	60
12. Linacre 1992	Mass transfer-based	PET = f (u, T, RH)	0.822	61
3. Trabert 1896	Mass transfer-based	PET = f (u, T, RH)	0.821	62
103. mod. Makkink (Doorenbos and Pruitt 1977)	Combination	PET = f (Rs, u, T, RH)	0.820	63
18. Malmstrom 1969	Temperature-based	PET = f (T)	0.820	64
19. Siegert and Schrodter 1975	Temperature-based	PET = f (T)	0.818	65
62. Abtew 1996 (1)	Radiation-based	PET = f (Rs)	0.816	66
91. Berengena and Gavilán 2005	Radiation-based	PET = f (Rs, T, RH)	0.811	67
31. Droogers and Allen 2002 (1)	Temperature-based	PET = f (T)	0.806	68
105. FAO24 Radiation	Combination	PET = f (Rs, u, T, RH)	0.806	69
20. Blaney and Criddle (Mid. Europ. Ver.)	Temperature-based	PET = f (T)	0.805	70
16. Hamon 1963	Temperature-based	PET = f (T)	0.805	71
26. Samani 2000	Temperature-based	PET = f (T)	0.800	72
17. Baier and Robertson 1965	Temperature-based	PET = f (T)	0.792	73
32. Droogers and Allen 2002 (2)	Temperature-based	PET = f (T)	0.786	74
89. Irmak et al. 2003 (5)	Radiation-based	PET = f (Rs, T, RH)	0.781	75
30. Xu and Singh 2001 (4)	Temperature-based	PET = f (T)	0.774	76
61. Christiansen 1968	Radiation-based	PET = f (Rs)	0.772	77
43. Heydari and Heydari 2014	Temperature-based	PET = f (T)	0.770	78
69. Caprio 1974	Radiation-based	PET = f (Rs, T)	0.769	79
115. Model 3	Temperature-based	PET = f (T)	0.769	80
127. Model 15	Radiation-based	PET = f (T, RH)	0.769	81
117. Model 5	Temperature-based	PET = f (T,RH)	0.768	82
7. Albrecht 1950	Mass transfer-based	PET = f (u, T, RH)	0.768	83
40. Tabari and Talaee 2011 (2)	Temperature-based	PET = f (T)	0.767	84
90. Irmak et al. 2003 (6)	Radiation-based	PET = f (Rs, T, RH)	0.766	85
22. Hargreaves and Samani 1985	Temperature-based	PET = f (T)	0.751	86
46. Althoff et al. 2019	Temperature-based	PET = f (T)	0.751	87
65. Jensen and Haise 1963	Radiation-based	PET = f (Rs, T)	0.746	88
25. Camargo et al. 1999	Temperature-based	PET = f (T)	0.745	89
95. Tabari and Talaee 2011 (4)	Radiation-based	PET = f (Rs, T, RH)	0.742	90
56. Ahooghalaandari et al. 2016 (1)	Temperature-based	PET = f (T, RH)	0.737	91
78. Irmak et al. 2003 (3)	Radiation-based	PET = f (Rs, T)	0.734	92
38. Trajkovic 2007	Temperature-based	PET = f (T)	0.733	93
15. McCloud 1955	Temperature-based	PET = f (T)	0.730	94
60. Droogers and Allen 2002 (3)	Temperature-based	PET = f (T, PR)	0.729	95
11. Szász 1973	Mass transfer-based	PET = f (u, T, RH)	0.729	96
41. Ravazzani et al. 2012	Temperature-based	PET = f (T)	0.727	97
42. Berti et al.2014	Temperature-based	PET = f (T)	0.727	98
33. Pereira and Pruit 2004	Temperature-based	PET = f (T)	0.723	99
35. Trajcovic 2005 (2)	Temperature-based	PET = f (T)	0.719	100
52. Naumann 1987	Temperature-based	PET = f (T, RH)	0.704	101
77. Irmak et al. 2003 (2)	Radiation-based	PET = f (Rs, T)	0.698	102
23. Kharrufa 1985	Temperature-based	PET = f (T)	0.697	103
44. Dorji et al. 2016	Temperature-based	PET = f (T)	0.691	104
39. Tabari and Talaee 2011 (1)	Temperature-based	PET = f (T)	0.687	105
45. Lobit et al. 2018	Temperature-based	PET = f (T)	0.678	106
57. Ahooghalaandari et al. 2016 (2)	Temperature-based	PET = f (T, RH)	0.671	107
54. Xu and Singh 2001 (6)	Temperature-based	PET = f (T, RH)	0.667	108
66. Stephens 1965	Radiation-based	PET = f (Rs, T)	0.656	109
51. Linacre 1977	Temperature-based	PET = f (T, RH)	0.653	110
6. Penman 1948	Mass transfer-based	PET = f (u, T, RH)	0.651	111
5. Rohwer 1931	Mass transfer-based	PET = f (u, T, RH)	0.644	112
47. Romanenko 1961	Temperature-based	PET = f (T, RH)	0.637	113

Table A5. *Cont.*

PET Method	Category	Form	sRPI	Rank
29. Xu and Singh 2001 (3)	Temperature-based	PET = f (T)	0.632	114
4. Meyer 1926	Mass transfer-based	PET = f (u, T, RH)	0.626	115
48. Papadakis 1965	Temperature-based	PET = f (T, RH)	0.617	116
87. Xu and Singh 2000	Radiation-based	PET = f (Rs, T, RH)	0.612	117
21. Smith and Stopp 1978	Temperature-based	PET = f (T)	0.590	118
14. Blaney and Criddle 1950	Temperature-based	PET = f (T)	0.588	119
1. Dalton 1802	Mass transfer-based	PET = f (u, T, RH)	0.575	120
49. Schendel 1967	Temperature-based	PET = f (T, RH)	0.543	121
94. Tabari and Talaee 2011 (3)	Radiation-based	PET = f (Rs, T, RH)	0.543	122
55. Xu and Singh 2001 (7)	Temperature-based	PET = f (T, RH)	0.540	123
50. Antal 1968	Temperature-based	PET = f (T, RH)	0.519	124
53. Xu and Singh 2001 (5)	Temperature-based	PET = f (T, RH)	0.487	125
8. Brockamp and Wenner 1963	Mass transfer-based	PET = f (u, T, RH)	0.296	126
2. Fitzgerald 1886	Mass transfer-based	PET = f (u, T, RH)	0.183	127

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