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Predicting Daily Reference Evapotranspiration in a Humid Region of China by the Locally Calibrated Hargreaves-Samani Equation Using Weather Forecast Data

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ABSTRACT

The Hargreaves-Samani (HS) equation, which estimates reference evapotranspiration (ET_0) using only temperature as input, should be most suitable for ET_0 prediction based on weather forecasting data. In the current study, the HS equation is calibrated with daily ET_0 by the Penman-Monteith equation, and is evaluated to check the possibility of predicting daily ET_0 based on weather forecast data. The HS equation is likely to overestimate daily ET_0 in the humid regions of China. Coefficients *a* and *c* are calculated as 0.00138 and 0.5736 according to local calibration. The calibrated HS equation performs considerably better than the original one. The proposed equation could be an alternative and effective solution for predicting daily ET_0 using public weather forecast data as inputs. The error of daily ET_0 prediction increases with the increase in the error of daily temperature range (TR) or daily mean temperature (T_{mean}). This error is likely to be more sensitive to the error in *TR* than in the T_{mean}. Ensuring that *TR* errors are less than 2°C is necessary for perfect estimations of ET_0 based on public weather forecast data using the calibrated HS equation.

Keywords: Hargreaves-Samani equation, Humid region, Local calibration, Reference evapotranspiration, Sensitivity analysis, Weather forecast data.

INTRODUCTION

The prediction of daily crop evapotranspiration (ET_c) is the basis for real-time irrigation forecasting. The estimation of ET_c often involves calculating the reference evapotranspiration (ET_0), which is defined as the evapotranspiration rate from a hypothetical crop with an assumed height of 0.12 m, a fixed surface resistance of 70 s·m^{-1}, and an albedo of 0.23 (Allen *et al.,* 1998). Subsequently, a suitable crop coefficient (K_c) is applied. The prediction of daily ET_0, which is the basis for estimating the daily ET_c and determining crop irrigation requirements, is essential for real-time irrigation forecasting.

The prediction of ET_0 is always realized based on either the weather forecast data (Duce *et al.,* 1999; Xu *et al.,* 2006; *Cai et al.,* 2007; Er-Raki *et al*., 2010) or time series analysis (Mariño *et al*., 1993; Mao, 1994; Mohan and Arumugam, 1995; Gu *et al*., 1998; Trajković, 1998; Luo *et al*., 2005; Landeras *et al*., 2009). Duce *et al*. (1999) calculated the hourly ET_0 using the modified Penman-Monteith (PM) equation, with outputs of a mesoscale weather forecast model as inputs. Xu *et al*. (2006) established a back propagation neural network model (BP-ANN) for the real-time prediction of ET_0 based on daily public weather forecast data. Cai *et al*. (2007) presented a complex analytical method for the estimation of ET_0

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by the FAO-56 PM equation using daily weather forecast messages, by which weather forecast messages were firstly transformed into data required before ET_0 was calculated by FAO-56 PM equation. Er-Raki *et al*. (2010) used the Hargreaves method to predict the daily ET_0 in semi-arid regions in the Tensift basin with climatic data generated by numerical weather prediction models as inputs. Thus, weather forecasting data are useful for the real prediction of ET_0 with different methods.

A number of methods have been developed for the estimation of ET_0 based on either (i) aerodynamic principles; (ii) energy budget; (iii) a combination of (i) and (ii); or (iv) empirical principles. The FAO PM combination equation (FAO-56 PM) has been proposed as the only standard method for calculating ET_0, and evaluating other equations (Allen *et al*., 1998). It is accepted worldwide as the optimum method and the standard for evaluating other methods (e.g., Jacovides and Kontonyiannis, 1995; Antonio, 2004; Hossein *et al*., 2004; Xu and Chen, 2005; López-Urrea *et al*., 2006; Trajkovic, 2007; Meshram *et al*., 2010; da Silva *et al*., 2011; Mohawesh, 2011). An issue that confronts us is that weather forecast data cannot meet the requirements for ET_0 calculation in many complex methods. The Hargreaves-Samani (HS) equation (Hargreaves and Samani, 1985), proposed as an alternative by Allen *et al.* (1998), may be most suitable for ET_0 prediction using weather forecast data because its estimated ET_0 merely uses temperature as input. However, debates continue regarding the HS equation. Several studies have reported that this equation may provide reasonable estimates of ET_0 (Hargreaves, 1994; Martinez-Cob and Tejero-Juste, 2004; Xu and Singh, 2002; Dinpasioh, 2006; Er-Raki *et al*., 2011); however, others argue that this equation tends to overestimate ET_0 in humid regions but underestimate ET_0 in very dry and windy regions (Samani, 2000; Droogers and Allen, 2002; Bakhtiari *et al*., 2011). Local calibration is strongly recommended prior to its application (Temessgen *et al*., 2005; Gavilan *et al*., 2006; Fooladmand and Haghighat, 2007; Er-Raki *et al*., 2010; Hu *et al*., 2011).

The objectives of the current study include providing an improved local calibration of the HS equation using the daily ET_0 by the FAO-56 PM equation in a humid region of China and evaluating its potential to use weather forecast data as inputs in the daily ET_0 prediction by the calibrated HS equation.

MATERIALS AND METHODS

Site Description and Data Collection

The Nanjing climate station (31°15′15″N, 120°57′43″E) was selected as the typical climate station in humid region in East China. The study area has a subtropical monsoon climate with an average annual air temperature of 16.3°C and a mean annual precipitation of 1,062.4 mm. Historical observed meteorological data (1995–2007) and public weather forecast data (2004–2005) were collected. The observed data set used in the current study was collected from the Chinese Meteorological Data Sharing Service System (http://cdc.cma.gov.cn). The data set is composed of daily values of the maximum air temperature (T_{max}), minimum air temperature (T_{min}), average temperature (T_a), atmospheric pressure (P), air humidity (RH_a), solar radiation (R_s), net radiation (R_n), and 24 hours wind speed at a height of 2 m (u_2). The data were measured following the Surface Meteorological Observation Standard of China Meteorological Administration (CMA, 2003) over a "25×25 m^2, well-watered, uniform height (less than 20 cm)" surface. Data quality was checked according to Quality Control of Surface Meteorological Observational Data (CMA, 2010) before it was published on the Chinese Meteorological Data Sharing Service System. The meteorological data have good quality and integrity. Statistics of the historical observed meteorological data from 1995 to

2007 are listed in Table 1. The observed meteorological data are divided into two groups. Data from 1995 to 2005 were used for the local calibration of the HS equation, and the remaining data (2006 to 2007) were set apart for validation. Before the data were used for daily ET_0 calculation using the FAO-56 PM equation (Allen *et al*., 1998), they were checked according to Allen (1996) by comparing the clear sky radiation (R_{so}) with solar radiation (R_s), as indicated in Figure 1.

Daily public weather forecast data, collected from Nanjing Daily, were composed of daily values of the T_{max} and T_{min}. Prediction errors of the forecast T_{max} and T_{min} are plotted in Figure 2, compared with the observed meteorological data. Errors of the daily T_{max} and T_{min} ranged from -3.3 to 3.0°C and -3.2 to 2.8°C, with an average of -0.244 and -0.242°C, respectively. Statistical analysis revealed that 51.3% of the forecast daily T_{max} and 51.3% of the forecast daily T_{min} had an error of no more than 1°C, and that 89.9% of the forecast daily T_{max} and 91.8% of the forecast daily T_{min} had an error no more than 2°C.

HS Equation: Calibration and Validation

The *HS* equation (Hargreaves and Samani, 1985) is as follows:

$$ET_0 = 0.408 \times a \times (T_{mean} + b) \times TR^c \times R_a \quad (1)$$

Where, T_{mean} and TR are the daily mean air temperature and daily temperature range (°C), respectively. Here, T_{mean} and TR are calculated based on the daily T_{max} and T_{min}, with T_{mean}= $(T_{max}+T_{min})/2$ and TR= $(T_{max}-T_{min})$. The parameter R_a is the extraterrestrial radiation (MJ m^{-2} d^{-1}) that depends on the day of the year and the latitude. It can be computed according to the method described by Allen *et al*. (1998). The coefficient b= 17.8 is used to convert the temperature *F* into °C. However, the coefficients *a* and *c*, with the original values of 0.0023 and 0.5, respectively, should be determined according to the local calibration.

Table 1. Statistics of historical observed meteorological data from 1995 to 2007.

Statistics		T_{max} (°C)	T_{min} (°C)	T_a (°C)	P (Kpa)	RH_a (%)	R_s (MJ m^{-2} d^{-1})	R_n (MJ m^{-2} d^{-1})	u_2 (m s^{-1})
Calibration	Maximum	40.0	30.0	34.3	104.3	98	32.3	17.9	5.83
data (1995 -	Minimum	-2.6	-8.0	-4.5	99.1	19	0	-2.2	0
2005)	Average	20.9	12.6	16.3	101.5	74	12.2	5.42	1.46
Validation	Maximum	38.2	29.0	33.1	104.0	95	28.2	15.2	5.70
data (2006-	Minimum	0.7	-5.6	-2.0	99.6	31	0	-1.8	0. 2
2007)	Average	21.8	13.4	17.2	101.5	71	12.3	5.1	1.96

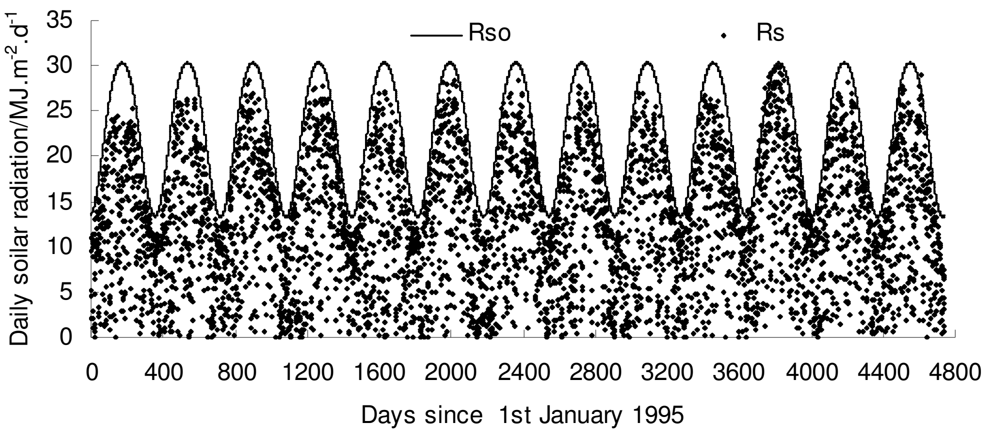

Figure 1. Comparison between daily solar radiation (R_s) and clear sky radiation (R_{so}).

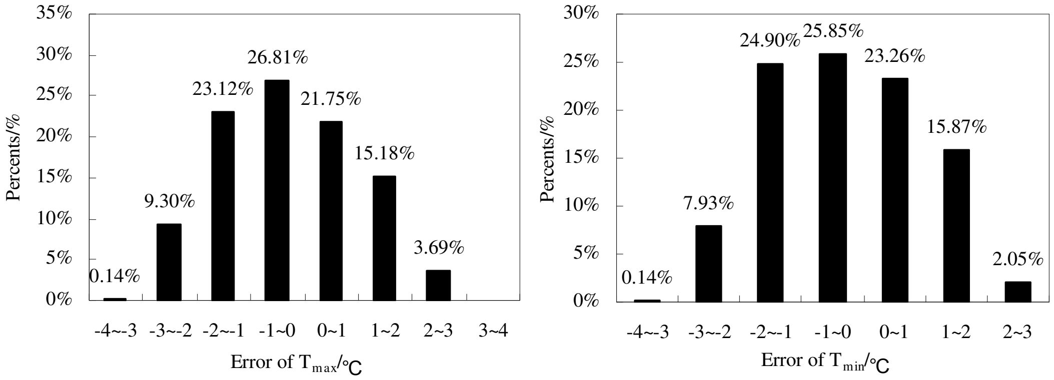

Figure 2. Prediction errors of T_{max} and T_{min} in public weather forecast compared with observed data.

Based on historical observed meteorological data from 1995 to 2005, local calibration was performed to determine the values of coefficients a and c through nonlinear multiple regression between the ET_0 calculated using the FAO-56 PM equation and T_{mean}, T_{max} T_{min}, and R_a. The nonlinear multiple regressions were realized by the 1stOPT software with Levenberg-Marquart (LM) algorithm. The locally calibrated HS equation was validated for the data from 2006 to 2007 by comparing the results with those using the FAO-56 PM equation.

Performance of Calibrated HS Equation Based on Weather Forecast Data

The ET_0 was predicted based on public weather forecast data (2004 to 2005) using Equation (1), with the locally calibrated coefficients of a and c. The prediction results with the calibrated *HS* equation were evaluated by comparing them with those calculated using the FAO-56 PM equation based on the historical observed climatic data.

Sensitivity Analysis of ET_0 Prediction to Weather Forecast Error

Errors on the weather forecast data and its influence on the accuracy of ET_0 predication must be discussed before they are used as inputs of the locally calibrated HS equation. Eighteen combinations of errors in the T_{max} and T_{min} were designed (Table 2), and the polluted data groups were acquired by imposing combinations of errors in the T_{max} and T_{min} of the historical observed climatic data (2004 to 2005). The ET_0 was then calculated using the calibrated HS equation with the polluted data groups as inputs, and

Table 2. Eighteen combinations of errors in T_{max} and T_{min} for sensitivity analysis of ET_0 prediction to weather forecast error.

Error in $TR(T_{mean})$		Error in T_{max}				
		-2°C	-1°C	0°C	1°C	2°C
Error in T_{min}	-2°C	0(-2)	1(-1.5)	2(-1)	3(-0.5)	4(0)
	-1°C	-1(-0.5)	0(-1)	1(-0.5)	2(0)	3(0.5)
	0°C	OM	-1(-0.5)	0 (0)	1(0.5)	2(1)
	1°C	OM	OM	-1(0.5)	0 (1)	1 (1.5)
	2°C	OM	OM	OM	-1(1.5)	0 (2)

OM means omitted, because those combinations of error in T_{max} and T_{min} are likely to lead to contradiction.

compared with those calculated by the FAO-56 PM equation based on historical observed climatic data.

Statistical Analysis

For the comparison of the ET_0 calculated by different equations or different input data sets, linear regressions with zero interception were made, and slopes and determination coefficients (R^2) were calculated. The average absolute errors (AE) and root mean square error (RMSE) were also calculated using the following expressions:

$$AE = \frac{1}{n}\sum_{i=1}^{n}(|P_i - O_i|) \quad (2)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)^2} \quad (3)$$

RESULTS AND DISCUSSION

Calibration and Validation of HS Equation

The HS equation is likely to overestimate daily ET_0 in a humid region in China, compared with the ET_0 by the FAO-56 PM equation. Approximately 88.7% of all the results overestimated daily ET_0. The average overestimation is 1.12 mm d^{-1}. Thus, local calibration was carried out with the ET_0 by the FAO-56 PM equation as a standard. The coefficients *a* and *c* were calculated as 0.00138 and 0.5736. Coefficient *a* in the current study is much lower than the original value suggested by Hargreaves and Samani (1985) and results of Gavilan *et al*. (2006), but falls within the range suggested by Moges *et al*. (2003) and Hu *et al*. (2011). The coefficient *c* in the current study is higher than the original value suggested by Hargreaves and Samani (1985) and by Trajkovic el al. (2007), but lower than the results of Hu *et al*. (2011). The daily ET_0 calculated by the *HS* equation and the locally calibrated equation were compared with those obtained by the FAO-56 PM equation (Figure 3). The results show the slopes to be 1.2738 and 0.9323, and the R^2 to be 0.5211 and 0.6234 for the original and locally calibrated *HS* equations, respectively. The average *AE*s are 1.05 and 0.56 mm d^{-1}, and the *RMSE*s are 1.26 and 0.71 mm d^{-1} for the original and locally calibrated HS equations, respectively.

The locally calibrated *HS* equation was validated with data from 2006 to 2007

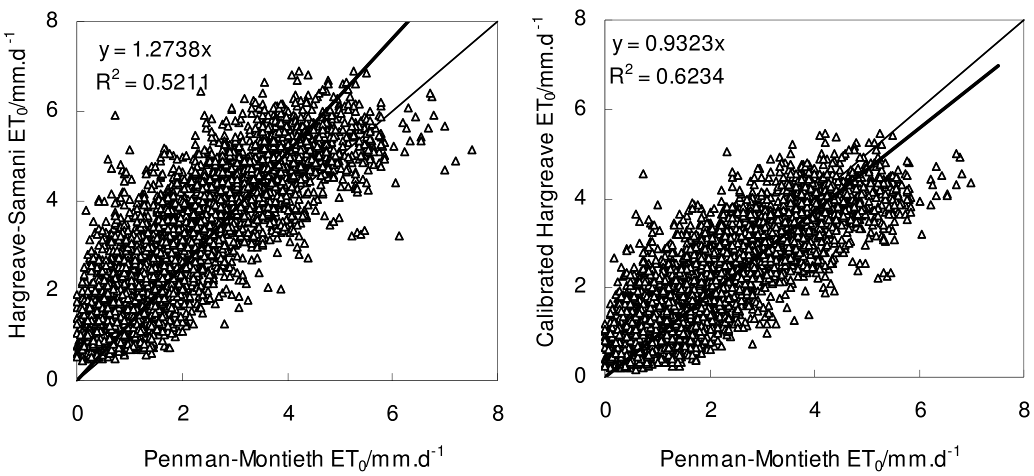

Figure 3. Comparison between the daily ET_0 calculated by the FAO-56 Penman-Monteith equation and the Hargreaves-Samani equation with the original and locally calibrated parameters for calibration data (1995-2005, N=3985).

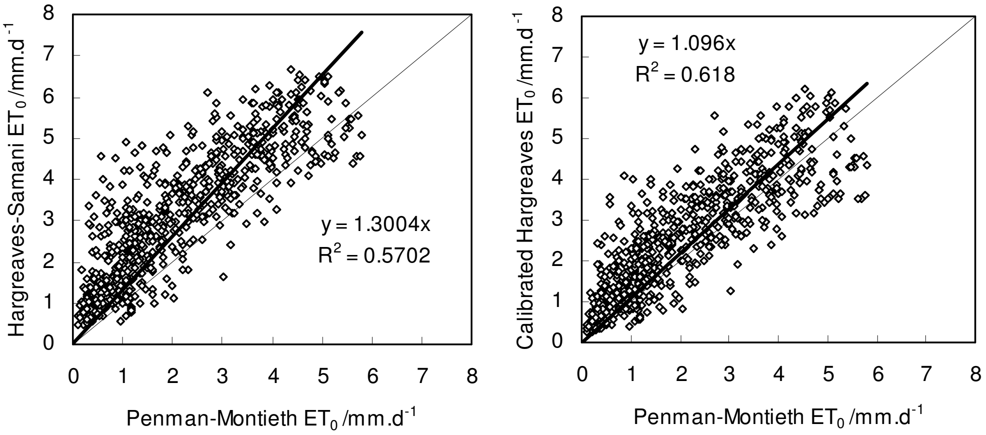

Figure 4. Comparison between the daily ET_0 calculated by the FAO-56 Penman-Monteith equation and the Hargreaves-Samani equation with the original and locally calibrated parameters for validation data (2006-2007, N= 729).

(Figure 4), by comparing with the ET_0 by the FAO-56 PM equation. The slope and R^2 of the linear regression between the ET_0 by the locally calibrated *HS* equation and the FAO-56 PM equation are 1.096 and 0.618, respectively. However, the slope and R^2 of the linear regression between the ET_0 by the original *HS* equation and the FAO-56 PM equation are 1.300 and 0.570, respectively. The *AE* and *RMSE* between the ET_0 by the locally calibrated *HS* equation and the FAO-56 PM equation are 0.61 and 0.77 mm d^{-1}, lower than the *AE* (0.97 mm d^{-1}) and *RMSE* (1.22 mm d^{-1}) between the ET_0 by the original *HS* equation and the FAO-56 PM equation. The locally calibrated *HS* equation performs considerably better than the original *HS* equation. The locally calibrated *HS* equation performs much better than the original *HS* equation for ET_0 calculation in the humid regions of East China.

For validation data sets, 66 and 171 data groups underestimate the ET_0 by the *HS* and the calibrated *HS* equations, respectively, compared with the ET_0 by the FAO-56 PM equation. However, 662 and 557 data groups overestimate ET_0. The underestimated ET_0 most likely occurred during windy days. The average wind speeds are 2.9 and 2.7 m s^{-1} for the underestimated cases, but 1.8 and 1.7 m s^{-1} for the overestimated cases. More than 80% of the underestimated cases have a wind speed higher than 2.5 m s^{-1}, and more than 80% have a wind speed lower than 2.0 m s^{-1}. These findings are consistent with the conclusion that the *HS* equation underestimates the ET_0 in very dry and windy regions (Samani, 2000; Droogers and Allen, 2002; Bakhtiari *et al.*, 2011). This can be ascribed to the advection phenomena related to the high aerodynamic term during windy days, which has been omitted in the HS equation.

Performance of Calibrated HS Equation Based on Weather Forecast Data

The ET_0s were predicted using the original and calibrated *HS* equations (Equation 1) based on the weather forecast data (2004 to 2005). The results plotted in Figure 5 were compared with the ET_0 calculated using the FAO-56 PM equation based on measured climatic data (2004 to 2005). The total predicted ET_0s by the original and calibrated *HS* equations during from 2004 to 2005 are 2262.1 and 1576.5 mm, 45.2 and 1.1% higher than the ET_0 by the FAO-56 PM equation. The slope for linear regressions between the predicted ET_0 by the calibrated *HS* equation and the ET_0 by the FAO-56 PM equation (R^2= 0.6497) is 0.9247, and 1.267

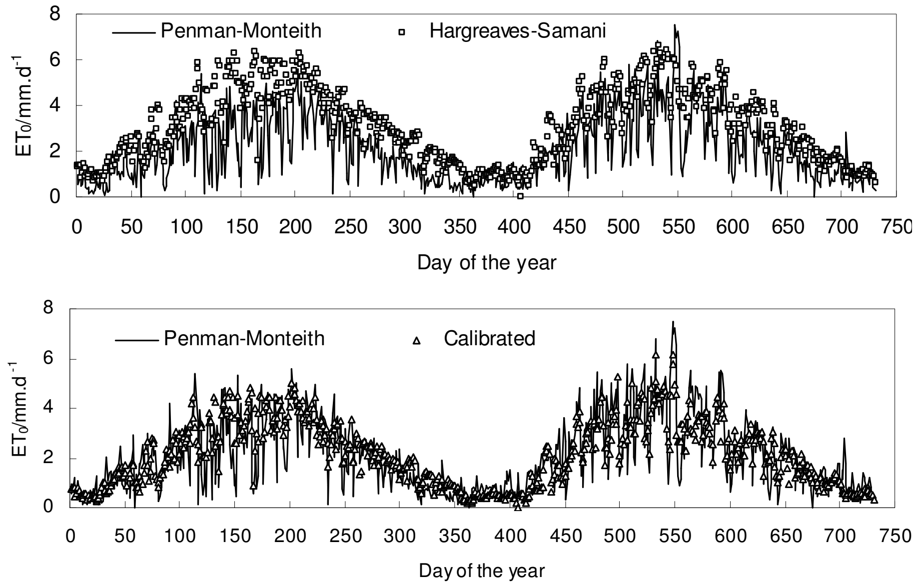

Figure 5. Comparison between the ET_0 predicated by using the Hargreaves-Samani equation based on weather forecast data and ET_0 calculated by the FAO-56 Penman-Monteith equation based on measured climatic data(2004-2005, N= 728).

for linear regressions between the predicted ET_0 by the original *HS* equations and the ET_0 by the FAO-56 PM equation (R^2= 0.4810). The average *AE* are 1.09 and 0.61 mm d^{-1}, and the *RMSE* are 1.33 and 0.79 mm d^{-1}. The average values of the *RMSE* are larger than the results by the analytical method in humid and semi-humid regions in China (Cai *et al.*, 2007). This result is near to that by the neural network model (Xu *et al.*, 2006) in humid regions in China and by the *HS* method (Er-Raki *et al.*, 2010) in semi-arid regions in Morocco. Thus, the *HS* equation always overestimates the ET_0 based on weather forecast data, compared with those calculated by the FAO-56 PM equation. Moreover, the calibrated *HS* equation performs considerably better than the original one in humid regions in China.

Both average *AE* and *RMSE* of the ET_0 prediction by the calibrated *HS* equation are relatively high, with 0.61 and 0.79 mm d^{-1} for the one using weather forecast data as input, and 0.61 and 0.77 mm d^{-1} for the one using observed meteorological data. Thus, both the original and locally calibrated *HS* equations are not good solutions for ET_0 calculation in humid regions in East China. However, assuming the simplicity and minimum data requirements of the *HS* equation, as well as the fact that public daily weather forecast data are always composed of limited information for the maximum temperature, minimum temperature, wind scale, and climate conditions, the locally calibrated *HS* equation could be an alternative and effective solution for predicting daily ET_0 using public weather forecast data as inputs. The proposed method may be useful for real-time irrigation forecasting. Nevertheless, further efforts should be made to improve the calibration of the *HS* equation and the accuracy of the weather forecast.

Sensitivity of ET_0 Prediction to Weather Forecast Error

Slopes, determination coefficients (R^2), average *AE*, and *RMSE* were calculated by comparing the ET_0 by the calibrated *HS* equation based on polluted data groups (see Table 2) and the results by the FAO-56 PM equation based on historical observed climatic data (Figure 6). The slopes range

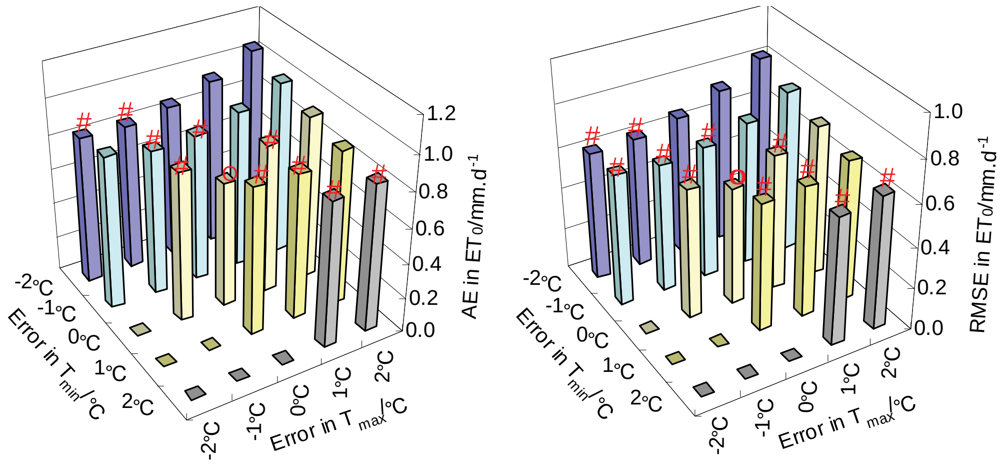

Figure 6. Average absolute errors (AE) and root mean square errors (RMSE) between ET_0 calculated by the calibrated Hargreaves-Samani equation based on polluted data groups and by the FAO-56 Penman-Monteith equation based on historical observed climatic data. (O on the column means the case with zero error in temperature prediction. # on the column indicates the AE less than 0.85 mm d^{-1} or RMSE less than 0.65 mm d^{-1}**).**

Table 3. Slopes and determination coefficients of regressions between ET_0 by the calibrated Hargreaves-Samani equation based on polluted data groups and that by the FAO-56 Penman-Monteith equation based on historical observed climatic data.

Slope (R^2)		Error in T_{max}				
		-2°C	-1°C	0°C	1°C	2°C
Error in T_{min}	-2°C	0.8496(0.6346)	0.9207(0.6196)	0.9912(0.6041)	1.0612(0.5887)	1.131(0.5735)
	-1°C	0.8043(0.6416)	0.8784(0.6272)	0.9514(0.6115)	1.0237(0.5953)	1.0954(0.5972)
	0°C	OM	0.8311(0.6347)	0.9247(0.6497)	0.9821(0.6031)	1.0562(0.5862)
	1°C	OM	OM	0.858(0.6276)	0.9361(0.6116)	1.0128(0.5944)
	2°C	OM	OM	OM	0.8848(0.6202)	0.9649(0.6035)

OM means omitted, because those combinations of error in T_{max} and T_{min} are likely to lead to contradiction. Shaded cell indicates that the polluted data group results in increased slope.

from 0.8043 (T_{max} -2°C, T_{min} -1°C) to 1.131 (T_{max}+2°C, T_{min} -2°C). The shaded cell in Table 3 indicates that the polluted data group results in the increased slope. The slope increases with the increase in the daily maximum temperature or the reduction in the daily minimum temperature. The error in T_{max} and T_{min} is converted into the change in temperature range *TR* and daily mean temperature T_{mean} (as listed in Table 2). Clearly, the slope increases with the increase in error in *TR* or T_{mean}, and the slope is likely to be more sensitive to error in *TR* than T_{mean}. The RMSE ranges from 0.827 (T_{max}-1°C, T_{min}-1°C) to 1.057 mm d^{-1} (T_{max}+2°C, T_{min} -2°C), and average AE ranges from 0.612 (T_{max}+1°C, T_{min}+2°C) to 0.833 mm d^{-1} (T_{max}+2°C, T_{min}-2°C). RMSE and AE also increase with the increase in the errors of the *TR* or T_{mean}, and are more sensitive to errors in *TR* than those in T_{mean}. If the setting for *AE* that is less than 0.65 mm d^{-1} and *RMSE* that is less than 0.85 mm d^{-1} are permissible in the ET_0 prediction based on weather forecast data, acceptable polluted data groups are likely to fall in a narrow range with errors in *TR* of no more than 1°C along the diagonal line (*TR* error equals 0°C) in Table 2. If the setting for *AE* that is less than 0.70 mm d^{-1} and *RMSE* that is less than 0.90 mm d^{-1} are permissible, the acceptable polluted data groups are likely to fall in the range in which the error in *TR* is no higher than 2°C. In fact, approximately 70 and 90%

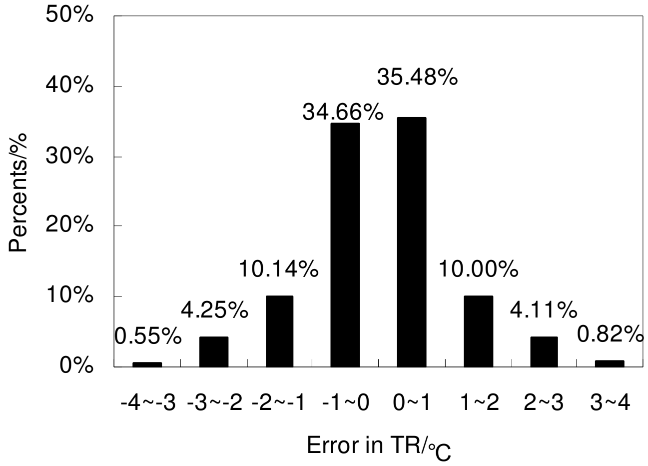

Figure 7. Prediction errors of daily temperature range (TR) in public weather forecast.

of the weather forecast fall in this range, with a *TR* error within -1 to 1°C and -2 to 2°C , respectively (see Figure 7).

CONCLOSIONS

The *HS* equation was tested and calibrated with the daily ET_0 calculated by the FAO-56 PM equation, and its capability to predict the daily ET_0 by this equation based on weather forecast data was evaluated. The *HS* equation is likely to overestimate the daily ET_0, as indicated in other studies carried out in humid regions. Local calibration of the *HS* equation is quite essential for ET_0 estimation in humid regions in China. The coefficients of *a* and *c* are calculated as 0.00138 and 0.5736, according to the local calibration. The average *AE* and *RMSE* of the ET_0 by the calibrated *HS* equation based on either observed climatic data or public weather forecast data are much lower than those by the original *HS* equation. The locally calibrated *HS* equation performs much better than the original *HS* equation. Furthermore, it could be an alternative and effective solution for predicting daily ET_0 using public weather forecast data as inputs, especially in real-time irrigation forecasting. The influence of weather forecast accuracy on daily ET_0 predication using the locally calibrated *HS* equation was also discussed. The error in the daily ET_0 predication increases with the increase in the error of the daily *TR* or daily T_{mean}. This error is apparently more sensitive to the error in *TR* than that in the T_{mean}. Ensuring a *TR* error of less than 2°C is necessary for perfect estimation of ET_0 based on public weather forecast data using the calibrated *HS* equation.

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پیش بینی تبخیر و تعرق مرجع روزانه منطقه‌ای مرطوب در چین با کالیبراسیون محلی معادله هارگریوز- سامانی با استفاده از داده‌های پیش‌بینی آب و هوا

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چکیده

معادله هارگریوز-سامانی(HS) ، که تبخیر و تعرق مرجع (ET_0)را فقط با استفاده از درجه حرارت به عنوان ورودی برآورد می کند، باید مناسب‌ترین راه برای براورد ET_0 بر اساس اطلاعات پیش‌بینی وضع هوا باشد. در مطالعه حاضر، معادله HS با ET_0 روزانه به‌دست آمده از معادله پنمن-مونتیث کالیبره شده و ارزیابی شده است تا امکان پیش‌بینی ET_0 روزانه بر اساس اطلاعات پیش‌بینی وضع هوا بررسی گردد. معادله HS به احتمال زیاد ET_0روزانه در مناطق مرطوب چین را زیاد براورد می‌کند. با

توجه به کالیبراسیون محلی، ضرایب a و c به میزان ۰/۰۰۱۳۸ و ۰/۵۷۳۶ محاسبه شدند. معادله HS کالیبره شده به‌طور قابل توجهی بهتر از معادله اصلی عمل نمود. معادله پیشنهادی می‌تواند یک راه حل جایگزین و موثر برای پیش‌بینی ET_0 روزانه با استفاده از داده‌های پیش بینی آب و هوای عمومی به عنوان ورودی باشد. خطای پیش‌بینی ET_0 روزانه با افزایش خطای دامنه دمایی روزانه (TR) و یا درجه حرارت متوسط روزانه (Tmean) افزایش می‌یابد. این خطا به احتمال زیاد نسبت به خطا در TR از خطا در Tmean حساس‌تر است. برای برآورد صحیح ET_0 بر اساس داده‌های عمومی پیش‌بینی هوا با استفاده از معادله HS کالیبره شده، اطمینان از خطای کمتر از ۲ درجه سانتی گراد TR لازم است.