FACTA UNIVERSITATIS
Series: **Architecture and Civil Engineering** Vol. 9, N^o 3, 2011, pp. 473 - 480
DOI: 10.2298/FUACE1103473T

ESTIMATING HOURLY REFERENCE EVAPOTRANSPIRATION FROM LIMITED WEATHER DATA BY SEQUENTIALLY ADAPTIVE RBF NETWORK

UDC 551.573:004.032.26:551=111

Slaviša Trajković

Faculty of Civil Engineering and Architecture, University of Niš, Serbia
slavisa.trajkovic@gaf.ni.ac.rs

Abstract. *This study investigates the utility of adaptive Radial Basis Function (RBF) networks for estimating hourly grass reference evapotranspiration (ET0) from limited weather data. Nineteen days of micrometeorological and lysimeter data collected at half-hour intervals during 1962-63 and 1966-67 in the Campbell Tract research site in Davis, California were used in this study. Ten randomly chosen days (234 patterns) were selected for the RBF networks training. Two sequentially adaptive RBF networks with different number of inputs (ANNTR and ANNTHR) and two Penman-Monteith equations with different canopy resistance values (PM42 and PM70) were tested against hourly lysimeter data from remaining nine days (200 patterns).*

The ANNTR requires only two parameters (air temperature and net radiation) as inputs. Air temperature, humidity, net radiation and soil heat flux were used as inputs in the ANNTHR. PM equations use air temperature, humidity, wind speed, net radiation and soil heat flux density as inputs. The results reveal that ANNTR and PM42 were generally the best in estimating hourly ET0. The ANNTHR performed less well, but the results were acceptable for estimating ET0. These results are of significant practical use because the RBF network with air temperature and net radiation as inputs could be used to estimate hourly ET0 at Davis, California.

Key words: *evapotranspiration, neural networks, temperature, net radiation, lysimeters.*

1. INTRODUCTION

Accurate estimates of hourly reference evapotranspiration (ET_o) are important for adequate management of irrigation systems. In the past several years many papers have evaluated various equations for calculating the hourly ET_o (Ventura et al. 1999, Lecina et al. 2003, Berengena and Gavilan 2005, Allen et al. 2006, Lopez-Urrea et al. 2006, Gavilan et al. 2007, Trajkovic 2009b). These studies have indicated the superiority of the

---

Received August 11, 2011
Acknowledgement. The paper is a part of the research done within the project TR037003.

Penman-Monteith equation for estimating hourly ET_o. The Penman-Monteith equation has two advantages over many other equations. First, it can be used globally without any local calibrations due to its physical basis. Secondly, it is a well documented equation that has been tested using a variety of lysimeters. The FAO-56 Penman-Monteith combination equation (FAO-56 PM) has been recommended by the Food and Agriculture Organisation of the United Nations (FAO) as the standard equation for estimating reference evapotranspiration (ET_o). The FAO-56 PM equation requires numerous weather data: air temperature, relative humidity, wind speed, net radiation and soil heat flux. The main shortcoming of this equation is that it requires numerous weather data that are not always available for many locations.

The purpose of this paper is to develop an adaptive Radial Basis Function (RBF) networks for hourly estimation of ET_o from limited weather data and to be able to accurately estimate hourly values of ET_o compared against lysimeter data.

In this paper, two sequentially adaptive RBF networks with different number of inputs (ANNTR and ANNTHR) and two FAO-56 Penman-Monteith equations with different canopy resistance values (PM42 and PM70) were evaluated against hourly lysimeter data from Davis, California.

2. MATERIALS AND METHODS

2.1. Study area and data collection

The Campbell Tract research site in Davis (38°32' N; 121 ° 46' W; 18 m above sea level) is characterized with the semiarid Mediterranean climate. Lysimeters in use at Davis consist of the two units. The weighting lysimeter was installed in 1958-59. This lysimeter is circular, 6.1 m in diameter, and a depth of 0.91 m. The floating drag-plate lysimeter, identical in size to the earlier one, was installed in 1962. In the period 1959-67 both lysimeters were in grass (perennial ryegrass, 1959-63; alta fescue, 1964-67) and were located about 52 m apart near the middle of 5.2 ha grass field. The soil in and around the lysimeters was disturbed Yolo loam**.** The grass was maintained at height between 8 and 15 cm until optimal water conditions. Irrigations were applied following a 0.075 m depletion of soil moisture. The ET_o data were measured in kg of weight loss from the weighting lysimeter and converted to standard units (1 kg h^{-1}= 0.008554 mm h^{-1}). Comparison was made for the 1966-67 data with ET from the floating drag-plate lysimeter, and agreement within 2% was usual.

The micrometeorological data were taken from smoothen profiles (at heights of 50, 100, 140, and 200 cm) of temperature, humidity and wind. Wet- and dry-bulb thermopile sensors gathered the profile data for temperature and humidity. A separate system measured profiles of absolute humidity using an infrared hydrometer as the sensor. Thornthwaite cup anemometers gathered wind profile data. Net radiation was measured at 2 m above the grass surface with a forced-ventilated radiometer. The soil heat flux was measured as the mean of three heat flux plates buried at 0.01 m depth in the soil.

The available data were collected at half-hour intervals during 1962-63 and 1966-67 (Pruitt and Lourence 1965; Morgan et al. 1971). Nineteen days of micrometeorological and lysimeter data were used for training and testing RBF networks (Table 1). There were few nighttime data provided, so only data during daylight hours were analyzed. This data set had a total of 436 patterns.

Table 1. Daily micrometeorological and lysimeter data at Davis, CA

Date	Time	Number of patterns	Training /Testing	T (^oC)	RH (%)	R_n ($kJm^{-2}s^{-1}$)	U_2 ($m\ s^{-1}$)	ET_{o_lys} ($mm\ day^{-1}$)
30/07/62	14.00-20.00	12	Training	26.5	38.5	0.234	4.0	5.11
31/07/62	06.00-18.30	23	Training	24.2	42.4	0.382	3.0	11.14
31/08/62	07.00-19.00	23	Training	26.2	41.6	0.333	1.2	8.32
30/10/62	10.00-17.00	15	Training	20.4	65.6	0.236	1.4	3.70
14/08/63	06.00-20.00	29	Training	27.1	36.6	0.290	2.0	11.76
15/08/63	06.00-19.30	28	Training	29.7	31.1	0.304	2.4	12.80
01/06/66	14.30-20.00	12	Testing	18.8	40.9	0.211	5.7	4.39
02/06/66	06.00-20.00	29	Training	17.7	43.3	0.343	2.9	11.60
03/06/66	06.00-20.00	29	Training	19.3	37.8	0.326	2.8	11.20
12/07/66	10.00-20.00	21	Testing	21.1	56.4	0.354	3.0	9.01
13/07/66	06.00-20.00	29	Testing	20.9	56.5	0.324	3.4	12.18
14/07/66	06.00-20.00	29	Testing	21.0	51.9	0.324	2.5	11.82
02/05/67	09.00-19.00	21	Training	18.7	47.4	0.385	2.6	8.31
03/05/67	12.30-19.00	14	Testing	19.0	46.4	0.296	2.5	5.33
04/05/67	07.00-19.00	25	Training	16.2	65.0	0.359	3.1	8.70
05/05/67	06.30-17.00	22	Testing	13.9	71.6	0.240	3.5	4.87
09/05/67	06.00-18.00	25	Testing	14.5	73.6	0.184	5.5	4.94
28/09/67	10.00-20.00	21	Testing	25.3	51.7	0.228	4.3	8.22
29/09/67	06.30-19.30	27	Testing	22.5	60.7	0.213	3.7	8.79

2.2. FAO-56 Penman-Monteith equation

The FAO-56 PM equation for hourly calculations can be expressed as (Allen et al. 1998):

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{37}{T+273}U_2(e_a - e_d)}{\Delta + \gamma(1 + \frac{r_c}{r_a})} \tag{1}$$

where ET_o = reference evapotranspiration (mm h^{-1}); Δ = slope of the saturated vapor pressure curve (kPa $^oC^{-1}$); R_n =net radiation (MJ m^{-2} h^{-1}); G =soil heat flux(MJ m^{-2} h^{-1}); γ = psychrometric constant; T = mean air temperature (^oC); U_2 = wind speed at a 2 meters height (m s^{-1}); (e_a-e_d) = vapor pressure deficit (kPa), r_a = aerodynamic resistance (s m^{-1}) and r_c = canopy resistance (s m^{-1}).

The Allen et al. (1998) recommended the use of r_c = 70 s m^{-1} for hourly time period. However, using canopy resistance equal 42 s m^{-1}, FAO-56 PM equation (PM42) best matched measured evapotranspiration in Davis (Ventura et al. 1999; Pruitt, personal communication, 2000). Todorovic (1999) found out that when the canopy resistance is calculated for Davis data by his model, the r_c values resulted in an average value of 40 s m^{-1} for most days.

2.3. Artificial neural networks

ANNs offer a relatively quick and flexible means of modeling, and as a result, application of ANN modeling is widely reported in the evapotranspiration literature (Trajkovic et al. 2000; Kumar et al. 2002; Kisi 2006; 2007). Recent papers have reported that ANNs may offer a promising alternative for estimation of daily evapotranspiration from limited weather data (Sudheer et al. 2003; Trajkovic 2005, 2009, 2010; Trajkovic et al. 2008, Zanetti et al. 2007). In this study, a sequentially adaptive Radial Basis Function (RBF) network from Trajkovic et al. (2003) was applied to estimating hourly ET_o.

Data set (436 patterns) was divided into two groups. For the RBF network training, ten randomly chosen days (234 patterns) were used (Table 1). For verification of RBF network, obtained in a stage of training, the remaining nine days (200 patterns) were used.

The RBF networks were trained with weather data as inputs, and ET_o as output. Two RBF networks with different number of inputs (ANNTHR and ANNTR) were considered. Air temperature, humidity, and (R_n-G) term were used as inputs in ANNTHR. As opposed to the Penman-Monteith equation, the ANNTHR did not use the wind speed for the ET_o calculation. After the completed training, ANNTHR has the following structure: in the input layer, there are three neurons which receive information on air temperature (T_a), humidity (H), and (R_n-G) term, in the hidden layer, there are four neurons, and in the output layer, there is one neuron giving the ET_o value.

$$ET_{o,annthr} = \sum_{i=1}^{4} a_i \exp\left[-\left(\left(\frac{T_a - m_{i1}}{\sigma_{i1}}\right)^2 + \left(\frac{H - m_{i2}}{\sigma_{i2}}\right)^2 + \left(\frac{(R_n - G) - m_{i3}}{\sigma_{i3}}\right)^2\right)\right] + \Theta \tag{2}$$

where a_i = weight of the i-th Gaussian basis function, m_{i1} = center of the i-th basis function for first input, σ_{i1} = width of the i-th basis function for first input, m_{i2} = center of the i-th basis function for second input, σ_{i2} = width of the i-th basis function for second input, m_{i3} = center of the i-th basis function for third input, σ_{i3} = width of the i-th basis function for third input, and θ = bias ($\theta = 0.06035$ for the ANNTHR).

The ANNTR requires only two parameters (air temperature and net radiation) as inputs. ANNTR did not use wind speed, relative humidity and soil flux density for estimating ET_o. After the completed training, ANNTR has the following structure: in the input layer, there are two neurons which receive information on air temperature and net radiation, in the hidden layer, there are five neurons, and in the output layer, there is one neuron giving the ET_o value.

$$ET_{o,anntr} = \sum_{i=1}^{5} a_i \exp\left[-\left(\left(\frac{T_a - m_{i1}}{\sigma_{i1}}\right)^2 + \left(\frac{R_n - m_{i2}}{\sigma_{i2}}\right)^2\right)\right] + 0.4146 \tag{3}$$

2.4. Evaluation parameters

Several parameters can be considered for the evaluation of ET_o estimates. In this study the following statistic criteria were used: root mean squared error (RMSE) and daily deviation (D). The RMSE values were calculated as:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(ET_{o\_est,i} - ET_{o\_ly,i})^2} \tag{4}$$

where $ET_{o\,est,i}$ = estimated half-hourly ET_o, $ET_{o\_ly,i}$ = half-hourly lysimeter ET_o, and n is number of observations. The RMSE value less than 0.074 mm h^{-1} is acceptable for most practical purposes (Ventura et al. 1999).

Daily deviation is estimated using equation:

$$D = \left(\frac{ET_{o\_est}}{ET_{o\_ly}} - 1\right)100 \tag{5}$$

where $ET_{o\,est}$ = daily sum of half-hourly ET_o estimates, $ET_{o\,ly}$ = daily sum of half-hourly lysimeter measurements.

3. RESULTS AND DISCUSSION

Two sequentially adaptive RBF networks with different number of inputs (ANNTR and ANNTHR) and two Penman-Monteith (PM) equations with different surface resistance values (PM42 and PM70) were compared against hourly lysimeter data from verification data set (nine days). The results of this comparison are presented in Table 2. The ANNTHR performed reasonable well for most days. This approach underestimated hourly ET_o for the second half of June 1, 1966, and midday of September 28, 1967, and overestimated first half of September 29, 1967. The *D* statistic was -14%, -11.1% and 1.3%, respectively. *RMSE* values were within acceptable range for all days excluding the September 28, 1967 (*RMSE*=0.095 mm h^{-1}), and September 29, 1967 (*RMSE*=0.079 mm h^{-1}). On average, ANNTHR underestimated hourly ET_{o_ly} by about 4% with RMSE value equal 0.058 mm h^{-1}.

Table 2. Statistical summary of hourly ET_o estimates at Davis, CA

Date	Parameters	ANNTHR	ANNTR	PM70	PM42
01/06/66	ET_{o_est} mm day^{-1}	3.774	3.629	3.618	4.168
ET_{o_ly} =	*D* (%)	-14.0	-17.3	-17.5	-5.0
4.387 mm day^{-1}	*RMSE* (mm h^{-1})	0.062	0.071	0.075	0.026
12/07/66	ET_{o_est} mm day^{-1}	8.744	9.311	7.616	8.370
ET_{o_ly} =	*D* (%)	-2.9	+3.3	-15.5	-7.1
9.010 mm day^{-1}	*RMSE* (mm h^{-1})	0.039	0.037	0.086	0.049
13/07/66	ET_{o_est} mm day^{-1}	11.510	12.320	10.591	11.734
ET_{o_ly} =	*D* (%)	-5.5	+1.1	-13.1	-3.7
12.182 mm day^{-1}	*RMSE* (mm h^{-1})	0.064	0.051	0.081	0.040
14/07/66	ET_{o_est} mm day^{-1}	11.783	12.245	10.510	11.388
ET_{o_ly} =	*D* (%)	-0.3	+3.6	-11.1	-3.6
11.817 mm day^{-1}	*RMSE* (mm h^{-1})	0.040	0.033	0.068	0.037
03/05/67	ET_{o_est} mm day^{-1}	5.006	5.129	4.298	4.680
ET_{o_ly} =	*D* (%)	-6.4	-3.7	-19.4	-12.2
5.328 mm day^{-1}	*RMSE* (mm h^{-1})	0.052	0.041	0.096	0.075
05/05/67	ET_{o_est} mm day^{-1}	4.816	5.014	4.224	4.877
ET_{o_ly} =	*D* (%)	-1.0	+3.0	-12.8	+0.2
4.866 mm day^{-1}	*RMSE* (mm h^{-1})	0.024	0.026	0.044	0.024
09/05/67	ET_{o_est} mm day^{-1}	4.913	4.975	4.084	4.911
ET_{o_ly} =	*D* (%)	-0.6	+0.7	-17.4	-0.6
4.941 mm day^{-1}	*RMSE* (mm h^{-1})	0.028	0.032	0.051	0.030
28/09/67	ET_{o_est} mm day^{-1}	7.306	8.483	7.314	8.094
ET_{o_ly} =	*D* (%)	-11.1	+3.3	-11.0	-1.5
8.215 mm day^{-1}	*RMSE* (mm h^{-1})	0.095	0.080	0.073	0.044
29/09/67	ET_{o_est} mm day^{-1}	8.921	9.651	7.438	8.335
ET_{o_ly} =	*D* (%)	+1.3	+9.6	-15.5	-5.3
8.806 mm day^{-1}	*RMSE* (mm h^{-1})	0.079	0.061	0.073	0.039
Average	ET_{o_est} mm day^{-1}	7.419	7.862	6.635	7.395
ET_{o_ly} =	*D* (%)	-4.0	+1.7	-14.1	-4.3
7.728 mm day^{-1}	*RMSE* (mm h^{-1})	0.058	0.050	0.071	0.041

Estimates by ANNTR were in closest agreement with the grass *ET* for most days. ANNTR underestimated hourly ET_{o_ly} for the second half of June 1, 1966, and overestimated first half of September 28, 1967, and September 29, 1967 with D value of -17.3%, 3.3%, and 9.6%, respectively. *RMSE* values were within acceptable range for all days excluding the September 28, 1967 (*RMSE*=0.080 mm h^{-1}). On average, this approach showed slight deviation of 1.7% relative to the ET_{o_ly} with RMSE value equal to 0.050 mm h^{-1}.

The deviation of ANNTHR and ANNTR on June 1, 1966, September 28, 1967, and September 29, 1967 may be partly due to high wind speed (average wind speed was 5.7, 4.3 and 3.7 m s^{-1}, respectively) and low net radiation (average net radiation was 0.211, 0.228, and 0.213 kJ m^{-2} s^{-1}, respectively). The average wind speed only in one of ten training days exceeded 3.1 m s^{-1}, and the average net radiation was not less than 0.234 kJ m^{-2} s^{-1} in any training day.

The ANNTHR and the ANNTR were especially successful on May 5, 1967, and May 09, 1967**.** These days had extreme values of micrometeorological data (the lowest air temperature, the highest relative humidity, very low net radiation and high wind speed). The ANNTHR and the ANNTR had the negligible departures from the ET_{o_ly}, even though the existence of the cloudiness produced high variations of the grass evapotranspiration during the day. The success is even greater, if it is emphasized that during the training days there were no days with such extreme values of the meteorological data.

The FAO-56 Penman-Monteith equation using the surface resistance r_c = 70 s m^{-1} (PM70) was the poorest in estimating ET_o of all equations evaluated. The PM70 consistently underestimated hourly ET_{o_ly} for all days by about 14%. The *RMSE* values varied from 0.044 (May 5, 1967) to 0.096 mm h^{-1} (May 3, 1967). These results strongly support the introduction of new value for surface resistance in the hourly FAO-56 PM equation recommended by Allen et al. (2006).

The PM42 yielded the excellent estimate of the grass ET for most days. This method underestimated ET_{o_lys} during July 12, 1966, and May 3, 1967 with daily deviation of -7.1% and 11.7%, respectively. RMSE value for May 3, 1967 slightly exceeded acceptable level of 0.074 mm h^{-1}(*RMSE* = 0.075). The PM42 consistently underestimated peak hourly ET_{o_lys} for all days by about 10%. On average, this method underestimated ET_{o_ly} by 4.3% with *RMSE* value equal to 0.041 mm h^{-1}.

The overall results indicate that ANNTR, ANNTHR, and PM42 give acceptable estimates of hourly ET_o. The ANNTR and PM42 were slightly better than ANNTHR at matching ET_{o_ly}. Figure 1 shows a comparison between estimated and measured ET_o on July 14, 1966.

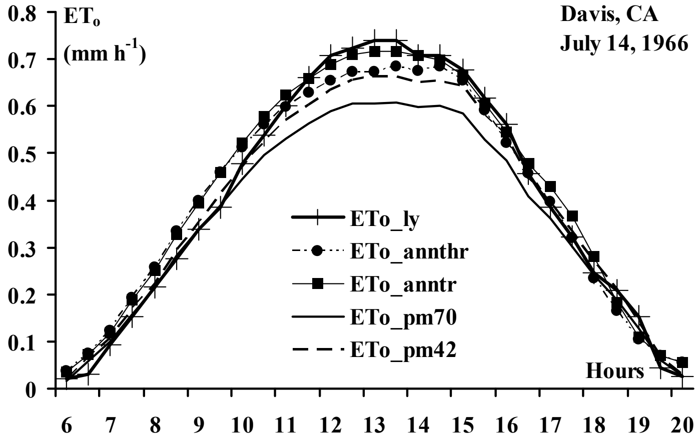

Fig. 1. Comparisons between estimated and measured ET_o at Davis on July 14, 1966

All of the equations paralleled $\mathrm{ET}_{\mathrm{o\_ly}}$ through the day. The PM70 consistently underestimated ET_{o_lys}. ANNTR, ANNTHR, and PM42 followed hourly ET_{o_lys} quite closely through the day. The ANNTHR slightly overestimated ET_{o_lys} in morning hours, and underestimated ET_{o_ly} in midday. The ANNTR slightly overestimated ET_{o_lys} in morning hours. The PM42 underestimated $\mathrm{ET}_{\mathrm{o\_ly}}$ in midday.

4. CONCLUSIONS

Two sequentially adaptive RBF networks with different number of inputs (ANNTR and ANNTHR) and two Penman-Monteith equations with different surface resistance values (PM42 and PM70) were tested against hourly daytime lysimeter data from Davis, CA.

The ANNTR requires only two parameters (air temperature and net radiation) as inputs. Air temperature, humidity, and (R_n-G) term were used as inputs in ANNTHR. PM equations use air temperature, humidity, wind speed, net radiation and soil heat flux as inputs. The results reveal that ANNTR and PM42 were generally the best in estimating hourly ET_{o}. The ANNTHR performed less well, but the results were acceptable for estimating ET_{o}.

This study indicates that the RBF network using limited weather data was able to reliably estimate hourly ET_{o} for a well-irrigated grass under different atmospheric conditions. The calculation of the hourly ET_{o} is possible only on the basis of the air temperature and the net radiation, without using the wind speed, humidity and soil flux density. These results are of significant practical use because the RBF network with air temperature and net radiation as inputs could be used to estimate hourly ET_{o} when relative humidity and wind speed data are not available. Although the RBF networks exhibit a tendency to obtain a generalized architecture, application of ANNTR to other areas needs to be studied.

REFERENCES

1. Allen, R. G., Pereira, L. S., Raes, D., and Smith, M. (1998). Crop Evapotranspiration. Guidelines for Computing Crop Water Requirements. *FAO Irrigation and Drainage Paper* 56, FAO, Roma, Italy.
2. Allen, R.G., Pruitt, W.O., Wright, J.L., Howell, T.A., Ventura, F., Snyder, R., Itenfisu, D., Steduto, P., Berengena, J., Yrisarry, J.B., Smith, M., Pereira, L.S., Raes, D., Perrier, A., Alves, A., Walter, I., and Elliot, R. (2006). "A recommendation on standardized surface resistance for hourly calculation of reference ET_{o} by the FAO56 Penman-Monteith method." *Agricultural Water Management*, 81(1-2): 1-22.
3. Berengena, J., and Gavilan, P. (2005). "Reference Evapotranspiration Estimation in a Highly Advective Semiarid Environment." *Journal of Irrigation and Drainage Engineering* 131(2), 147-163.
4. Gavilan, P., Berengena, J., and Allen, R.G. (2007). "Measuring versus estimating net radiation and soil heat flux: Impact on Penman-Monteith reference ET estimates in semiarid regions." *Agricultural Water Management* 89 (3), 275-286.
5. Kisi, O. (2006). "Generalized regression neural networks for evapotranspiration modeling." *Hydrological Sciences Journal* 51(6), 1092-1105.
6. Kisi O. (2007). Evapotranspiration modeling from climatic data using a neural computing technique. *Hydrological Processes* 21(14), 1925-1934.
7. Kumar, M., Raghuwanshi, N. S., Singh, R., Wallender, W. W., and Pruitt W. O. (2002). "Estimating Evapotranspiration using Artificial Neural Network." *Journal of Irrigation and Drainage Engineering,* 128 (4), 224-233.
8. Lopez-Urrea, R., de Santa Olalla, F. M., Fabeiro, C., and Moratalla, A. (2006). "An evaluation of two hourly reference evapotranspiration equations for semiarid conditions." *Agricultural Water Management* 86(3), 277-282.

9. Morgan, D.L., Pruitt, W.O., and Lourence, F.J. (1971). "Analyses of energy, momentum, and mass transfers above vegetative surfaces." *Res. and Dev. Tech. Report, ECOM, 68-G10-F*, University of California, Davis.
10. Pruitt, W.O., and Lourence, F.J. (1965). "Tests of aerodynamic, energy balance and other evaporation equations over a grass surface." *Ch. IV, Final report 1965, USAEPG*, Dept. of Water Science and Engineering, University of California, Davis.
11. Sudheer, K.P., Gosain, A. K., and Ramasastri K.S. (2003). "Estimating Actual Evapotranspiration from Limited Climatic Data Using Neural Computing Technique." *Journal of Irrigation and Drainage Engineering*, 129(3), 214-218.
12. Todorovic, M. (1999). Single-Layer Evapotranspiration Model with Variable Canopy Resistance. *Journal of Irrigation and Drainage Engineering*, ASCE, 125(5), 235-245.
13. Trajkovic, S. (2005). Temperature-Based Approaches for Estimating Reference Evapotranspiration, *Journal of Irrigation and Drainage Engineering*, 131(4), 316-323.
14. Trajkovic, S. (2009). "Comparison of Radial Basis Function Networks and Empirical Equations for Converting from Pan Evaporation to Reference Evapotranspiration." *Hydrological Processes,* 23 (6), 874-880.
15. Trajkovic, S. (2010). "Testing hourly reference evapotranspiration approaches using lysimeter measurements in a semiarid climate." *Hydrology Research,* 41(1), 38-49.
16. Trajkovic, S., Stankovic, M., and Todorovic B. (2000). "Estimation of FAO Blaney-Criddle b Factor by RBF Network." *Journal of Irrigation and Drainage Engineering* 126(4), 268-271.
17. Trajkovic, S., Todorovic, B., and Stankovic M. (2003). "Forecasting of Reference Evapotranspiration by Artificial Neural Networks." *Journal of Irrigation and Drainage Engineering,* 129(6), 454-457.
18. Trajkovic, S, Zivkovic, S., Todorovic, B. (2008) Proračun časovnih vrednosti evapotranspiracije veštačkim neuronskim mrežama, *Zbornik radova Gradjevinsko-arhitektonskog fakulteta u Nišu* 23, 231 – 242.
19. Ventura, F., Spano, D., Duce, P., and Snyder, R. L. (1999) An evaluation of common evapotranspiration equations. *Irrigation Science*, 18, 163-170.
20. Zanetti, S. S., Sousa, E.F., Oliveira, V. P. S., Almeida, F.T., and Bernardo S. (2007) "Estimating evapotranspiration using artificial neural network and minimum climatological data." *Journal of Irrigation and Drainage Engineering*, 133(2), 83-89.

PRORAČUN ČASOVNE REFERENTNE EVAPOTRANSPIRACIJE IZ MINIMALNOG BROJA KLIMATSKIH PODATAKA KORIŠĆENJEM SEKVENCIJALNE ADAPTIVNE RBF MREŽE

Slaviša Trajković

Ova studija istražuje pogodnost korišćenja adaptivnih RBF mreža za proračun časovnih referentnih evapotranspiracija iz minimalnog broja klimatskih podataka. Polučasovni podaci iz devetnaest dana sakupljanih 1962-63 and 1966-67 u Campbell Tract research site u Davis-u, California su korišćeni u ovoj studiji. Deset slučajno izabranih dana (234 podataka) su korišćeni za trening RBF mreža. Dve sekvencijalne adaptivne RBF mreže sa različitim brojem ulaza (ANNTR and ANNTHR) I dve Penman-Monteith jednačine sa različitim vrednostima površinskog otpora (PM42 and PM70) su testirane uporedjivanjem sa lizimetarskim podacima sa preostalih devet dana (200 podataka). ANNTR zahteva samo dva parametra (temperatura vazduha i neto radijacija) kao ulaze. Temperatura vazduha, vlažnost vazduha, neto radiacija i zemljišni toplotni fluks su korišćeni kao ulazi za ANNTHR. Rezultati pokazuju da su ANNTR i PM42 najbolji u proračunu časovnih ET_0*. Ovi rezultati su od velikog praktičnog značajazato što RBF mreža sa temperaturom vazduha i neto radijacijom može da se koristi za proračun časovne* ET_0*.*

Ključne reči: *evapotranspiracija, neuronske mreže, temperatura vazduha, neto radijacija, lizimetri.*