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COMPARATIVE STUDY OF TEMPERATURE-BASED POTENTIAL EVAPOTRANSPIRATION MODELS IN KINGDOM OF SAUDI ARABIA

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ABSTRACT

In this paper Potential evapotranspiration (PET) have been computed using two temperature-based empirical models ie., Hargreaves method (HM)and Thornthwaite method(TM) for three different cities Riyadh abha and Jeddah representing Arid, Moderate and Humid climate respectively in kingdom of Saudi Arabia. Climatic data from the weather stations, Riyadh,Abha, Jeddah respectively, were used to compute daily PET in accordance with the two temperature-based models.The result byHargreaves method shows that Riyadh has highest evapotranspiration rate per followed by Jeddah and the least value is found for Abha city.While the result obtained from Thornthwaite methodshows that Jeddah has highest evapotranspiration rate per year followed by Riyadh and the least value is found for Abha city .

Keywords: Evapotranspiration, Hargreaves method, Thornthwaite method, Mean Temperature, Heat Index

I. INTRODUCTION

The concept of Potential Evapo-Transpiration PET provides a convenient index to estimate the maximum water loss to the atmosphere. Estimates of PET are necessary in many of the rainfall-runoff and ecosystem models that are used in global change studies [2,6].

There are various models for estimating Potential Evapotranspiration PET. PET models are classified depend upon the weather parameters that play the dominant role in the model. The generally classification include: the temperature-based models [2,17]; Hargreaves and Samani[9]; the mass-transfer models (based of vapour pressure or relative humidity,[8,16]; the radiation models (based on solar radiation, [13,15], and the combination models (based on the energy balance and mass transfer principles, [1,5,14].

The temperature-based PET models are some of the earliest methods for estimating PET [18].Temperature-based model are simple to use and economical as they require less time and effort to apply them. There are list of temperature-based model, but [1] recommended the Hargreaves- Samani model (called the Hargreaves model) as the model that should be used to calculate PET when only air temperatures data are available for computing PET. Another temperature-based model that has been reported to be very convenient to use [10] and has better performance rating for semi-arid and arid conditions is the [11] model [7]. The Jensen-Haise model was classified as a solar radiation model [4,12].But air temperature plays a dominant role in the model expression. Therefore it can also be regarded as a temperature-based model..Temperature-based models have some limitations in terms of the extent of use. According to James[10], temperature based models are not as accurate as the Penman-type equations (the combination models) for period of less than 5 days. The American Society of Civil Engineers (ASCE) Irrigation Water Requirement Committee recommended the use of the Jensen-Haise method for estimating ETo for periods of 5 days to a month [4].

II STUDY AREA

The present work deals with three cities of Saudi Arabia-Jeddah, Riyadh and Abha representing different climatic condition-Humid, Arid & Moderate Climaterespectively**.** Jeddah is located at center of western Saudi Arabia. It is the largest city in Makkah Province, the largest sea port on the Red Sea, and the second-largest city in Saudi Arabia. Riyadh is the capital and largest city of Saudi Arabia. It is also the capital of Riyadh Province, and belongs to the historical regions of Najd and Al-Yamama. It is situated in the center of the Arabian Peninsula on a large plateau. Abha is the capital of Asir province in Arabia. It is located in the Southern Region of Asir. It is situated at (2,200 meters) above sea level. The city is generally mild throughout the year, though it's noticeably cooler during the "low-sun" season. Abha seldom sees temperatures rise above 35° C during the course of the year.

Fig. 1 Study Area

III. MATERIAL AND METHODS

Hargreaves and Samaniproposed several improvements to the Hargreaves equation for estimating grass-related reference *ET* (mm d^{-1}); one of them has the form:

$$ET = aR_aTD^{1/2}(Ta + 17.8) \qquad (1)$$

Where $a = 0.0023$ is a parameter;

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TD = the difference between maximum and minimum daily temperature in ◦C;

R_a= the extraterrestrial radiation expressed in equivalent evaporation units. For a given latitude and day $R_a$is obtained from tables .The only variables for a given location and time period is the daily mean, max and min air temperature. Therefore, the Hargreaves method has become a temperature-based method

The monthly PE according to Thornthwaite's method has been calculated from the following formula:

$$PE = 16 (10\ t/I)^a \qquad (2)$$

where PE -Potential evapotranspiration mm per month (month of 30 days each and 12 hours day time); t = mean temperature, °C; I = annual or seasonal heat index = summation of 12 values of monthly heat indices

$$\sum_{i=1}^{12}\left(\frac{t_i}{5}\right)^{1.514} \qquad (3)$$

(Here, ti = temperature in °C of ith month);

and a = an empirical exponent

$=0.675x10^{-6}I^3-0.771x10^{-4}I^2+0.1792x10^{-1}I+0.49239$

For the computation of Potential Evapotranspiration using Hargreaves empirical equation, Input datas are daily mean, max and min air temperature & also difference between max and min air temperature, Extra-terrestrial radiation While forThornthwaite's method month temperature and heat index are required which are given in table I, II, III. Also Fig 2 to 6 Shows Input data which are plotted to show monthly variation.

Table I Input Data for Jeddah

Month	a	tmin	tmax	Ta	TD	Ra
Jan	0.0023	18.3	29	23.7	10.7	4.30
Feb	0.0023	18.1	29.5	23.8	11.4	4.96
Mar	0.0023	19.4	31.8	25.6	12.4	5.69
Apr	0.0023	22.1	34.9	28.5	12.8	6.30
May	0.0023	24	37.2	30.6	13.2	6.59
Jun	0.0023	24.8	38.3	31.6	13.5	6.66
Jul	0.0023	26.6	39.4	33	12.8	6.62
Aug	0.0023	27.6	38.8	33.2	11.2	6.41
Sep	0.0023	26.4	37.6	32	11.2	5.93
Oct	0.0023	24.1	36.7	30.4	12.6	5.22
Nov	0.0023	22.3	33.5	27.9	11.2	4.48
Dec	0.0023	20	30.7	25.4	10.7	4.12

Table II Input Data for Riyadh

Month	a	tmin	tmax	Ta	TD	Ra
Jan	0.0023	6.8	20.1	13.5	13.3	4.00
Feb	0.0023	9.2	23.3	16.3	14.1	4.71
Mar	0.0023	13.2	27.7	20.5	14.5	5.52
Apr	0.0023	18.3	33.3	25.8	15	6.25
May	0.0023	23.4	39.4	31.4	16	6.64
Jun	0.0023	25.2	42.6	33.9	17.4	6.76
Jul	0.0023	26.4	43.7	35.1	17.3	6.70
Aug	0.0023	26.3	43.7	35	17.4	6.41
Sep	0.0023	22.8	40.6	31.7	17.8	5.82
Oct	0.0023	18.2	35.5	26.9	17.3	5.00
Nov	0.0023	13.4	28.2	20.8	14.8	4.19
Dec	0.0023	8.5	22.2	15.4	13.7	3.81

Table III Input Data for Abha

Month	a	tmin	tmax	Ta	TD	Ra
Jan	0.0023	7.7	19.6	13.7	11.9	4.62
Feb	0.0023	9.4	21.1	15.3	11.7	5.21
Mar	0.0023	11.1	23	17.1	11.9	5.85
Apr	0.0023	12.7	25.2	19	12.5	6.34
May	0.0023	14.8	28.6	21.7	13.8	6.52
Jun	0.0023	16.5	30.9	23.7	14.4	6.54
Jul	0.0023	17.1	30.5	23.8	13.4	6.51
Aug	0.0023	16.7	30.5	23.6	13.8	6.40
Sep	0.0023	14.9	29.5	22.2	14.6	6.04
Oct	0.0023	11.6	26	18.8	14.4	5.43
Nov	0.0023	8.9	23	16	14.1	4.78
Dec	0.0023	7.3	20.7	14	13.4	4.45

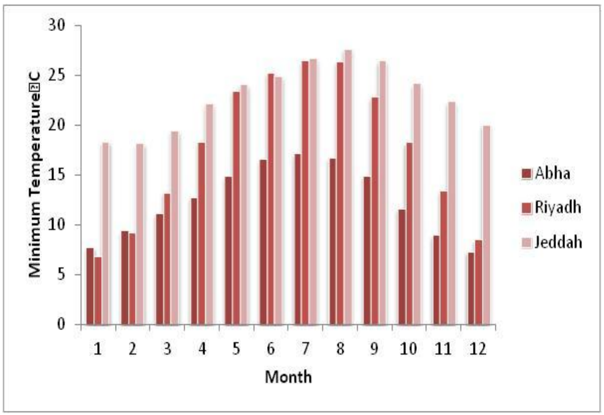

Fig. 2 Minimum Temperature per month

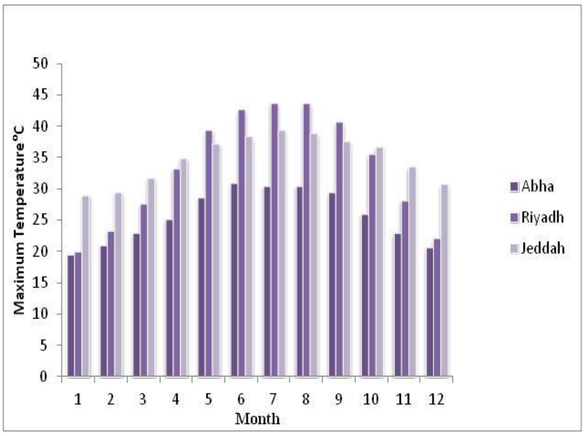

Fig. 3 Maximum Temperature per month

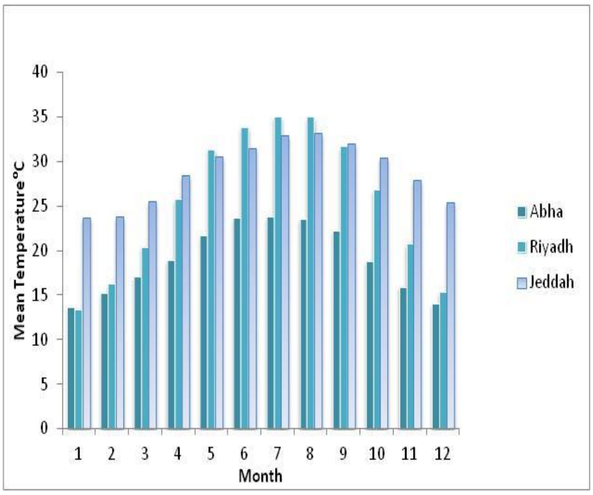

Fig. 4 Mean Temperature per month

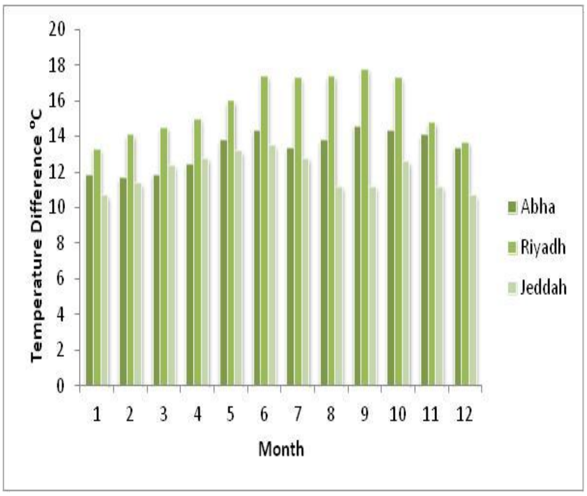

Fig. 5 Minimum Temperature difference per month

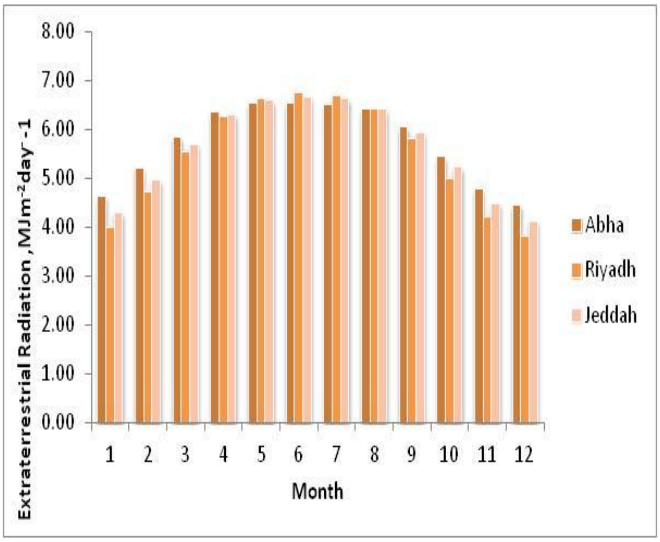

Fig. 6 Extraterristrial Radiation per month

IV. RESULT AND DISCUSSIONS

The mean monthly temperature in Riyadh area varies between 13.5° to 35.1°C ,Temperature difference varies between 13.3° to 17.8° and Extra-terrestrial Radiation varies from 3.81 to 6.76MJm^{-2}day^{-1}.In Jeddah, . The mean monthly temperature varies between 23.7° to 37.2°C ,Temperature difference varies between 10.7° to 13.5° and Extra-terrestrial Radiation varies from 4.12 to 6.66MJm^{-2}day^{-1}.In Abha the mean monthly temperature varies between 13.7° to 23.8°C ,Temperature difference varies between 11.7° to 14.6° and Extra-terrestrial Radiation varies from 4.45 to 6.54MJm^{-2}day^{-1}

The result computed for Potential Evapotranspiration using the temperature based empirical Equation Hargreaves method is plotted and in figure 7 &8 for three different climatic Condition i.e. Arid-Riyadh, Humid-Jeddah, Moderate-Abha.The result byHargreaves method shows that Riyadh has highest evapotranspiration rate per followed by Jeddah and the least value is found for Abha city.While the result obtained from Thornthwaite methodshows that Jeddah has highest evapotranspiration rate per year followed by Riyadh and the least value is found for Abha city

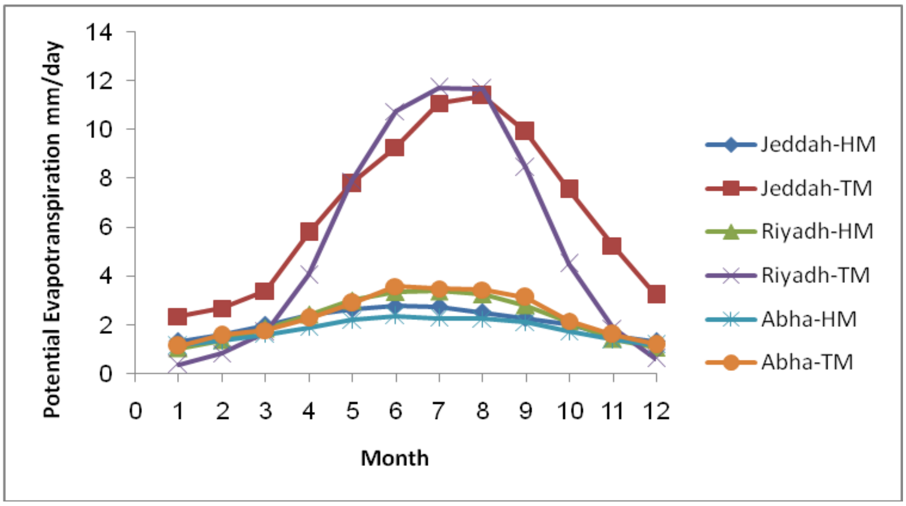

Fig.7 Potential Evapotranspiration per day

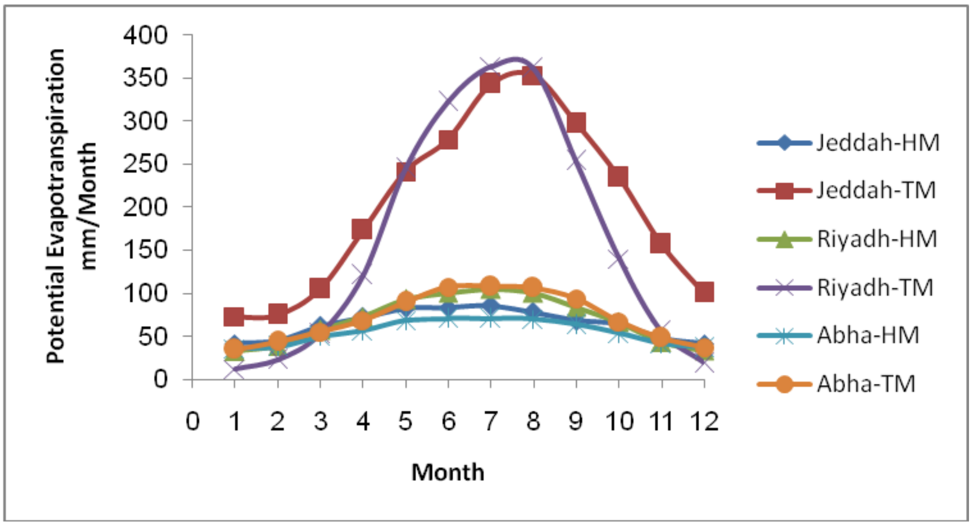

Fig.8 Potential Evapotranspiration per month

V CONCLUSION

Computation of Potential Evapotranspiration has been performed for three different Cities of Kingdom of Saudi Arabia.ie.,Riyadh, Jeddah &Abha showing different climatic conditions using two method .Weather data for Riyadh representing arid climate, Jeddah representing humid climate and Abha representing moderate climate were analyzed. The data was used for defining weather characteristics.Figure 7& 8 represents the daily &monthly variation of PET throughout the year. The graph obtained from Hargreaves method shows clearly for Riyadh the increasing trend of PET from January to July and there after decreasing trend up to December with highest value of 3.39mm/day for the month of July. For Jeddah the increasing trend of PET from January to June and there after decreasing trend up to December with highest value of 2.78mm/day for the month of June. For Abha the increasing trend of PET from January to July and there after decreasing trend up to December with highest value of 2.37 mm/day for the month of June. While The graph obtained from Thornthwaite's method shows clearly for Riyadh the increasing trend of PET from January to July and there after decreasing trend up to December with highest value of 11.73 mm/day for the month of July. For Jeddah the increasing trend of PET from January to August and there after decreasing trend up to December with highest value of11.4 mm/day for the month of August. For Abha the increasing trend of PET from January to june and there after decreasing trend up to December with highest value of 3.58 mm/day for the month of June. This indicates that there is higher need to manage the surface water resource and utilise the same for consumptive purposes.

REFERENCES

[1]. Allen, R. G., L. S. Pereira, D. Raes, and M. Smith. 1998. Crop Evapotranspiration – Guidelines for Computing Crop Water Requirements, FAO Irrigation and Drainage Paper 56.

[2]. Blaney, H. F. and W. D. Criddle. 1950. Determining water requirements in irrigated area from climatologically irrigation data. US Department of Agriculture, Soil Conservation Service, Tech. Paper No. 96.

[3]. Band, L.E., D.S. Mackay, and I.F. Creed, 1996. Ecosystem processes at the Watershed Sale: Sensitivity to Potential Climate Change.Limnol. Oceanogr. 41(5):928-938.

[4]. Burman, R.D., P. R. Nixon, J. L. Wright, W. O. Pruitt. 1980. Water Requirements. In: Design and Operation of Farm Irrigation Systems. (Jensen M. E., ed.). 189-232. ASAE Monograph No 3.

[5]. Doorenbos, J. and W. O. Pruitt. 1977. Crop Water Requirements, FAO, Irrigation and Drainage, Paper 24.

[6]. Hay, L.E. and G.J. McCabe, 2002. Spatial Variability in Water Balance Model Performance in the Conterminous United States.Journal of the American Water Resources Association (JAWRA) 38(3):847-860.

[7]. Hansen V.E., O.W. Israelson and G.E. Stringham. 1979. Irrigation Principles and Practice, 112-139. 4^{th} edition. New York: John Wiley and Sons.

[8]. Harbeck Jr., G. E. 1962. A practical field technique for measuring reservoir evaporation utilizing mass-transfer theory, 101-105. US. Geol. Survey paper 272-E.

[9]. Hargreaves, G. H. and Z. A. Samani. 1985. Reference crop evapotranspiration from temperature. Transaction of the ASAE 28(1): 96-99.

[10]. James L. G. 1988. Principles of Farm Irrigation System Design. New York: John Wiley and Sons, Inc.

[11]. Jensen, M. E. and H. R. Haise. 1963. Estimating evapotranspiration from solar radiation. Journal of Irrigation and Drainage Division, Proc. Amer. Soc. Civil Eng. 89:15–41.

[12]. Jensen, M. E., R. D. Burman and R. G. Allen. 1990. Evapotranspiration and Irrigation Water Requirements. , ASCE Manuals and Reports on Engineering Practices No 70. Am. Soc. Civil Engr., New York.

[13]. Makkink, G. F. 1957. Testing the Penman formula by means of Lysimeters', J. Inst. Water Engineers 11: 277–288.

[14]. Penman, H. L. 1948. Natural evaporation from open water, bare soil and grass. Proc., Royal Soc., London,193: 120–145.

[15]. Priestley, C. H. B. and R. J. Taylor. 1972. On the assessment of the surface heat flux and evaporation using large-scale parameters. Monthly Weather Review 100: 81–92

[16]. Rohwer, C. 1931. Evaporation from free water surface. USDA Tech. Bull. 217:1–96.

[17]. Thornthwaite, C. W. 1948. An approach toward a rational classification of climate. Geog. Review 38:55–94.

[18]. Xu, C. Y. and V. P. Singh. 2002. Cross comparison of empirical equations for calculating potential evaporation with data from Switzerland. Water Resource Management 16:197-219.