Analysis of Potential Evapotranspiration of different Cities of Kingdom of Saudi Arabia

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***Abstract*— Potential evapotranspiration (PET) is an important index of hydrologic budgets at different spatial scales and is a critical variable for understanding regional biological processes. It is often an important variable in estimating actual evapotranspiration (AET) in rainfall-runoff and ecosystem modelling. The Present work deals with Computation of Potential Evapotranspiration under different climatic conditions in Saudi Arabia using *Temperature based empirical equation-Thornthwaite* method. Weather data for Riyadh representing arid climate, Jeddah representing humid climate and Abha representing moderate climate were analyzed. These data contained Mean Temperature and heat index. The result shows that Jeddah has highest evapotranspiration rate per year because of humid climate followed by Riyadh which is having arid climate and the least value is found for Abha city due to moderate climate**

***Keywords*— Evapotranspiration, Average Temperature, Heat index, *Thornthwaite* method**

I. INTRODUCTION

Evapotranspiration has a great impact on many hydrological and meteorological processes. In spite of the efforts of several scientists, reliable estimates of regional evapotranspiration are extremely difficult to obtain mainly because of its dependence on soil conditions and plant physiology, so that advances in the knowledge of the underlying interactions and its all-round influence have been few and far between. Because of this complexity, the concept of potential evapotranspiration (PE) has been introduced, which no longer depends so critically on soil and plant factors but has been shown to primarily depend on climatic factors (Thornthwaite, 1948). PE is defined as the evapotranspiration that occurs when the ground is completely covered by actively growing vegetation under conditions of unlimited and unrestricted water supply. A number of empirical formulae have been developed for the determination of PE directly from meteorological data.. Several methods of estimating PE are presently in use, perhaps with the assumption that errors, if any, will be damped out upon averaging in space and time domains. Judging the accuracy of the available methods is also not easy. Even experimentally observed data have limitations due to the difficulties of simulating the ideal conditions as defined for PE. Therefore, the physical and dynamical nature of these formulae has to be taken as a guideline in evaluating the relative merits of the formulae.

Estimates of PET are necessary in many of the rainfall-runoff and ecosystem models that are used in global change studies (Band et al., 1996; Hay and McCabe, 2002). The PET concept has many application, it is regarded as a confusing term because the reference evaporation surface, usually the vegetation type, is vaguely defined (Nokes, 1995). As a result, the PET concept has been gradually replaced in the past decade by other defined terms, such as reference crop evapotranspiration (Jensen et al.,1990), or surface dependent evapotranspiration (Federer et al., 1996). Typically, reference crops are grass and alfalfa because most equations were developed for agricultural purposes, but a land surface can contain any designated vegetation types. Potential evapotranspiration can be measured directly by lysimeters, but generally, it is estimated by theoretical or empirical equations, or derived simply by multiplying standard pan evaporation data by a coefficient (Grismer et al., 2002). Because of the large size of a tree, there have been few attempts to directly measure forest PET or AET by lysimeter studies and develop associated equations to estimate PET or AET (Stein et al., 1995; Riekerk, 1985). Forest PET values at landscape levels are often indirectly estimated using modified mathematical models that were developed for free water surface or short crops, such as the Thornthwaite equation (Thornthwaite and Mather, 1955;Kolka and Wolf, 1998).

Past studies have suggested that different PET methods may give significantly different results (Crago and Brutsaert, 1992; Amatya et al., 1995; Federer et al., 1996; Vörösmarty et al., 1998). By using intensive meteorological data various methods for the computation of potential evapotranspiration *ET* have been derived which can be divided into five categories:(1) water budget (e.g. Guitjens, 1982), (2) masstransfer (e.g. Harbeck, 1962),(3) combination (e.g. Penman, 1948), (4) radiation (e.g. Priestley and Taylor, 1972), and (5) temperature-based (e.g. Thornthwaite, 1948; Blaney-Criddle, 1950). Recently study have been performed to compute Potential Evapotranspiration in various cities of Kingdom of Saudi Arabia (Saiful et al,2014,2015) The present study work deals with potential evapotranspiration (*ET*) estimation methods that require only temperature as an input variable are considered as temperature-based methods. The temperature-based methods are some of the earliest methods for estimating *ET*

II. Study Area

The present work deals with three cities of Saudi Arabia-Jeddah, Riyadh and Abha representing different climatic condition-Humid, Arid & Moderate Climate respectively. 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.1Study Area

III.Methodology

The required climatological data for the calculation of monthly PE have been collected from meteorological observatories in Kingdom of Saudi Arabia. The sources of data are the Monthly Weather Reports of the Saudi Meteorological Department and the Monthly Climatic Data for the World .The monthly PE according to Thornthwaite's method (Thornthwaite, 1948; Thornthwaite and Mather, 1955) has been calculated from the following formula:

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

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

$$= \sum_{i=1}^{12} (t_i/5)^{1.514}$$

(Here, ti = temperature in °C of ith month);
and a = an empirical exponent

$$= 0.675 \times 10^{-6} I^3 - 0.771 \times 10^{-4} I^2 + 0.1792 \times 10^{-1} I + 0.49239.$$

For the computation of Potential Evapotranspiration using Thornthwaite empirical equation, Input data's are daily mean temperature which is given in table I,. Also Fig 2 Shows Input data which are plotted to show monthly variation of mean temperature per month of three different climatic condition. The annual heat indices for Jeddah is 170.87,for Riyadh 146.48 and for abha it is 92.3 °C respectively.

TABLE I
MEAN TEMPERATURE

	Mean Temperature		
Month	Jeddah	Riyadh	Abha
Jan	23.65	13.45	13.65
Feb	23.8	16.25	15.25
Mar	25.6	20.45	17.05
Apr	28.5	25.8	18.95
May	30.6	31.4	21.7
Jun	31.55	33.9	23.7
Jul	33	35.05	23.8
Aug	33.2	35	23.6
Sep	32	31.7	22.2
Oct	30.4	26.85	18.8
Nov	27.9	20.8	15.95
Dec	25.35	15.35	14

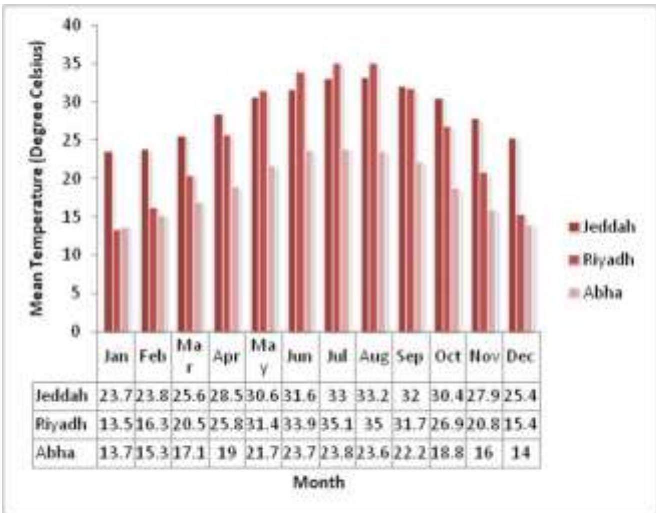

Fig.2 Monthly Mean Temperature

IV. Results and Discussion

The mean monthly temperature in Riyadh area varies between 13.5° C to 35.1°C , In Jeddah, . The mean monthly temperature varies between 23.7°C to 37.2°C , In Abha the mean monthly temperature varies between 13.7° to 23.8° C . The result computed for Potential Evapotranspiration using the temperature based empirical Equation Thornthwaite method is plotted in figure 3&4 and table II & III for three different climatic Condition i.e. Arid-Riyadh, Humid-Jeddah, Moderate-Abha. The result shows that jeddah has highest evapotranspiration

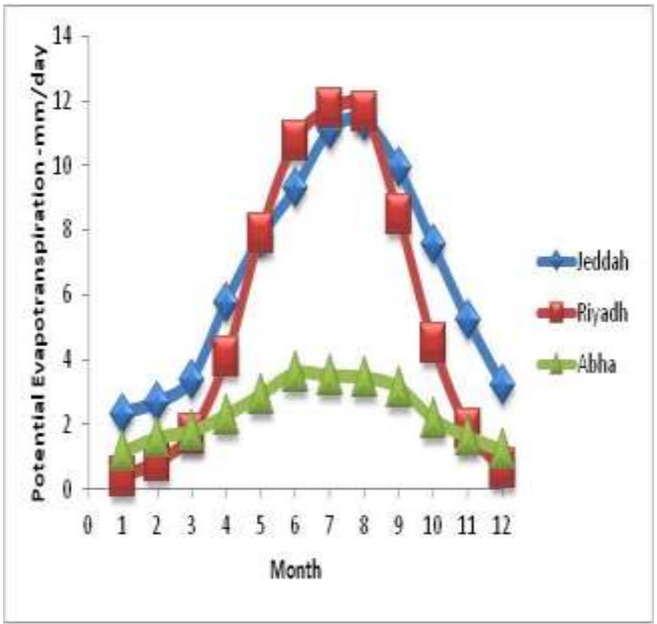

Fig. 3 Potential Evapotranspiration mm/day

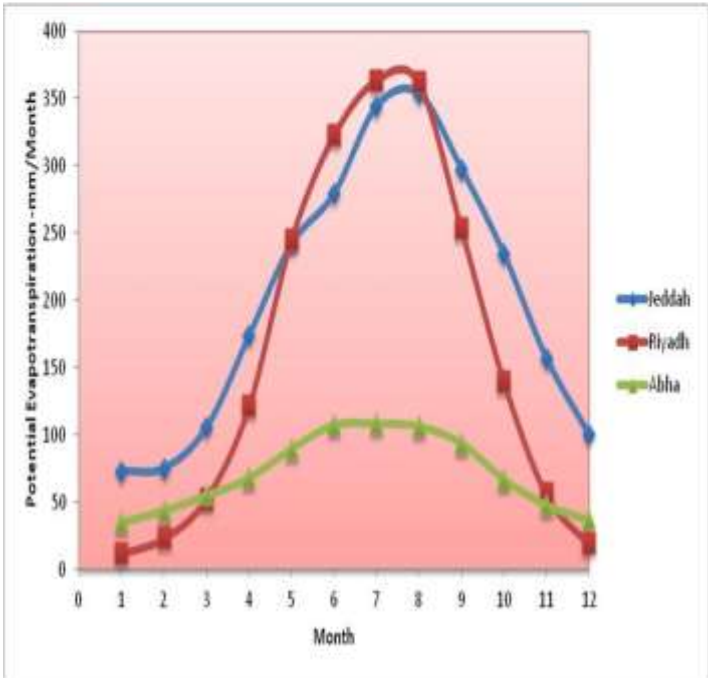

Fig. 4 Potential Evapotranspiration mm/month

TABLE II
POTENTIAL EVAPOTRANSPIRATION MM/DAY

	Potential Evapotranspiration-mm/day		
Month	**Jeddah**	**Riyadh**	**Abha**
Jan	2.35	0.38	1.14
Feb	2.68	0.83	1.58
Mar	3.40	1.70	1.78
Apr	5.79	4.05	2.28
May	7.80	7.91	2.90
Jun	9.29	10.76	3.58
Jul	11.09	11.73	3.50
Aug	11.40	11.67	3.44
Sep	9.93	8.46	3.14
Oct	7.56	4.52	2.17
Nov	5.24	1.87	1.61
Dec	3.24	0.61	1.20

TABLE III
POTENTIAL EVAPOTRANSPIRATION MM/MONTH

	Potential Evapotranspiration-mm/month		
Month	**Jeddah**	**Riyadh**	**Abha**
Jan	72.77	11.79	35.27
Feb	74.95	23.20	44.12
Mar	105.27	52.83	55.27
Apr	173.57	121.40	68.42
May	241.75	245.27	89.96
Jun	278.76	322.66	107.50
Jul	343.69	363.59	108.42
Aug	353.51	361.74	106.58
Sep	297.78	253.76	94.20
Oct	234.47	140.04	67.33
Nov	157.19	56.14	48.30
Dec	100.56	18.92	37.12

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 .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. These data contained hourly readings for mean air temperature, Figure 3 & 4 represents the daily &monthly variation of PET throughout the year. The graph 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

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