Monitoring of Potential Evapo-Transpiration of Abha City, Kingdom of Saudi Arabia

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***Abstract*— Evapotranspiration is a major component of hydrological cycle. Its estimation is important for water resource management purposes and for understanding soil water balance at a place. It is known to be dependent upon climatic factors. In this study, the potential evapotranspiration of the Abha city has been computed for three situations i.e. close ground crops, bare land and water surface considering it as a land use pattern of the city other than built up areas. The result obtained will help the water resource management of the city keeping in mind the climate variability factor. The data for various metrological factors, temperature, and wind speeds, relative humidity, sun shine hours and solar radiation for the period of (2003-2013) was collected from Metrological Department. Using the data, potential evapotranspiration was estimated using the internationally accepted PET version of Penman equation. The data was analyzed monthly. PET was found to show an increasing trend from January to June and decreasing trend from June to December having highest PET for the month June..**

***Keywords*— Potential Evapotranspiartion, Climate Change, Penman method**

I. INTRODUCTION

In the present era, more interest has been shown to climate variability and its effect on the hydrological cycle and water resources system [10]. Research has been reported to see the climate changes, trends and variability in various parts of the world utilizing the climate parameters such as temperature, precipitation, reference evapotranspiration ETo and pan evapotranspiration ETp [6-11]. Reference evapotranspiration is importance because it combine changes in many other climate parameters including temperature, solar radiation, humidity and wind velocity. It has, however, direct influence on hydrologic cycle, irrigation systems and reservoir operation of hydropower plant, potentials for rain-fed agricultural production and consumptive use of water [4], [5] concluded that the Saudi Arabia is suffering from a considerable warming trend form year 1980-2008. However, no regional scale study is reported to compute the potential evapotranspiration of water for different land use patterns in the Saudi Arabia which is very important for water resource management at the micro scale. The Abha city which is water scare area emphasis is given for precision farming systems to grow the vegetable crops so the finding of this study will directly help to precision farming system. Therefore, identifying changes in PET is necessary for future planning of agriculture-water projects in the Abha city.

The Kingdom of Saudi Arabia (KSA) is one of the most arid countries in the world and suffers water shortage problems. The Kingdom suffers large water supply deficit since more than 88% of water consumption is due to agricultural related activities [2]. Agricultural water requirements are determined initially by identifying the reference evapotranspiration (ETo). The main solution of the water problem is an efficient water use system and better projection for demand and supply. Rain in KSA is the only renewable water source and comes in short duration storms of high intensity and most of it vanishes to evaporation and surface runoff. Global warming or green house effect has been shown to affect the earth climate [8]. Some researchers developed a hypothetical scenario to study the effect of possible increase on temperature over the KSA on ETo and subsequently on water supply. A study conducted by [1] concluded that a 1°C increase in temperature would increase ETo from 1-4.5%. In another study, that includes selected cities in Saudi Arabia, United Arab Emirates and Kuwait, [3] concluded that an increase in temperature by 1°C would increase ETo over these area by a maximum of 20%. Moreover, studies involving ETo calculation seemed to be more limited worldwide compared to other climate parameters. Consequently, the aim of this study is to quantify potential evapotranspiration of Abha city at regional scale for water resource management using Penman equation.

II. STUDY AREA

An **A**bha 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 climate of Abha is cold semi-arid climate. The city is generally mild throughout the year, though it’s noticeably cooler during the “low-sun” season. Abha seldom sees temperatures rise above 35^0 C during the course of the year. The city averages 600 mm of rainfall annually, with the bulk of the precipitation occurring between February and April, with a secondary minor wet season of July and August. The map shown below in Figure number 1 depicts the location of the city in Asir region of the Kingdom of Saudi Arabia.

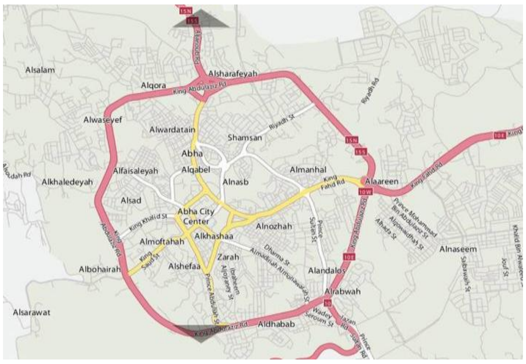

Fig.1: Map of Abha City located in Asir region in the Kingdom of Saudi Arabia.

The input data used for the computation of potential evapotranspiration is shown below. The data was obtained from the web portal of the Meteorological department of the Kingdom of the Saudi Arabia.

TABLE I

INPUT DATA OF THE WEATHER PARAMETERS USED IN PENMAN EQUATION

Month	Mean temperature C	R.H %	Wind speed km/day	N sunshine hours	n	solar radiation mm/day
JAN	13.3	70	311.904	11.2	9.4	11.2
FEB	14.9	67	355.9	11.55	9.8	12.4
MAR	16.8	62	355.9	12	8.3	14
APR	18.6	60	266.9	12.55	10	15.2
MAY	21.3	50	222.9	13	9.9	15.6
JUN	23.5	39	266.9	13.2	10	15.7
JUL	23.2	45	266.9	13.1	8	15.6
AUG	22.8	51	222.9	12.7	7.5	15.2
SEP	22.2	38	266.9	12.4	10	14.5
OCT	18.7	42	222.9	11.75	10	13.5
NOV	15.8	60	222.9	11.3	8.5	12.4
DEC	13.9	66	266.9	11	9.4	10.7

Source: Web portal Meteorological department Kingdom of Saudi Arabia

III. METHODOLOGY

Penman's equation is based on sound theoretical reasoning and is obtained by a combination of the energy-balance and mass transfer approach. Penman's equation, incorporating some of the modifications suggested by other investigators is:

$$PET = \frac{AH_n + E_a\gamma}{A+\gamma}$$

Where PET = daily potential evapotranspiration in mm per day

A = Slope of the saturation vapour pressure vs. temperature curve at the mean air temperature, in mm of mercury per degree centigrade.

H_n = Net radiation in mm of evaporable water per day

Ea = Parameter including wind velocity and saturation deficit

γ = Psychometric constant = 0.49 mm of mercury per degree centigrade

The net radiation is same as used in energy budget and is estimated by the following equation:

$$H_n = H_a(1-r)(a+b\frac{n}{N}) - \sigma T_a^4(0.56-0.092\sqrt{e_a})(0.1+0.9\frac{n}{N})$$

Where Ha = Incident solar radiation outside the atmosphere on a horizontal surface, expressed in mm of the evaporable water per day.

a =a constant depending upon the latitude

b = a constant with an average value of 0.52

n = actual duration of bright sunshine in hours

N = maximum possible hours of bright sun shine

r=reflection coefficient

σ = Stefan-Boltzman constant = 2.01X10^{-9} mm/day

T_a = Mean air temperature in degree Kelvin

e_a = actual mean vapour pressure in the air in mm of mercury

The parameter E_a is estimated as

$$E_a = 0.35(1+\frac{u_2}{160})(e_w - e_a)$$

Where

u_2 = mean wind speed at 2 m above ground in km/day

e_w = saturation vapour pressure at mean air temperature in mm of mercury

For the computation of PET, data on n, N e_a,u_2,mean air temperature,Solar radiation and nature of surface are needed. For calculation purpose the value of nature of surface for close ground crops is taken as 0.25,0.for bareland it is taken as 0.45 and for water surface it is taken as 0.05.the other above mentioned parameters are obtained from metereological data of the region.

IV. RESULTS

. The result obtained using the method above is tabulated in Table No.2 for three different cases i.e. close ground crops, bare land and water surface respectively excluding the built up area of the city.

TABLE II

PET VALVE OF THREE DIFFERENT CONDITION

Months	PET for Close ground crops (mm/day)	PET for bareland (mm/day)	PET for Water surface (mm/day)

Jan	2.91	1.98	3.85
Feb	3.75	2.65	4.84
Mar	4.56	3.42	5.7
April	5.06	3.68	6.44
May	5.57	4.14	7.01
June	6.52	5	8.03
July	6.02	4.7	7.34
Aug	5.32	4.06	6.58
Sep	5.96	4.53	7.38
Oct	4.75	3.47	6.03
Nov	3.48	2.43	4.52
Dec	2.82	1.9	3.54

The bar chart drawn for the three different conditions depicted in Figure No.2,3,4 and 5 represents the monthly variation of PET throughout the year. The chart shows clearly the increasing trend of PET from January to June and there after decreasing trend upto December with highest value for the month of June.

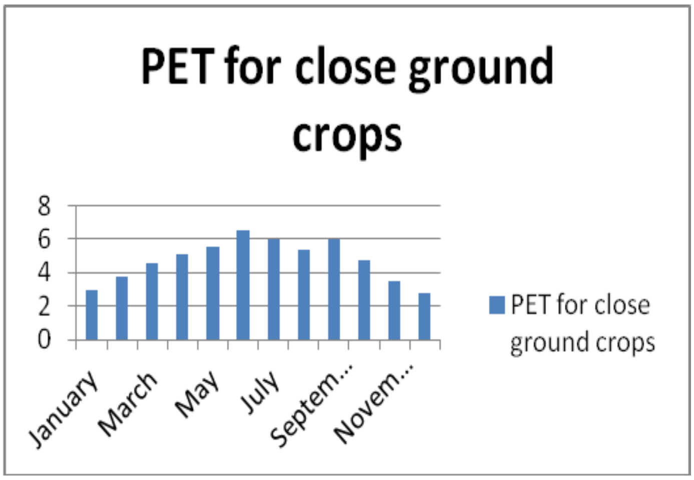

Fig 2. Monthly PET variation for the close ground crops

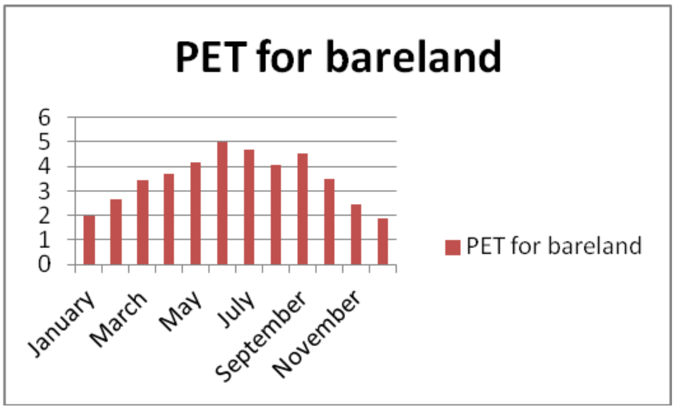

Fig.3. Monthly PET variation of bare land

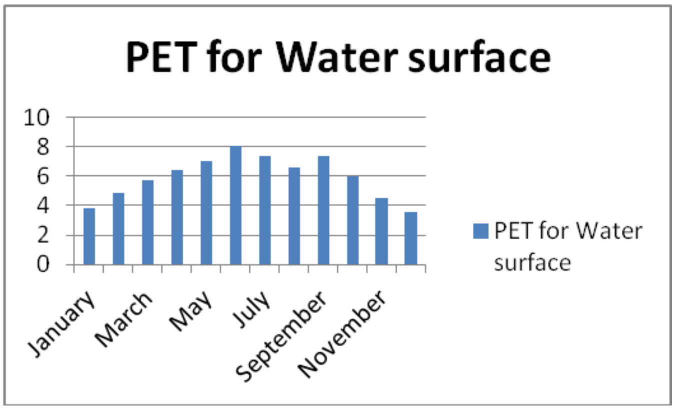

Figure No.4: Monthly PET variation of water surface

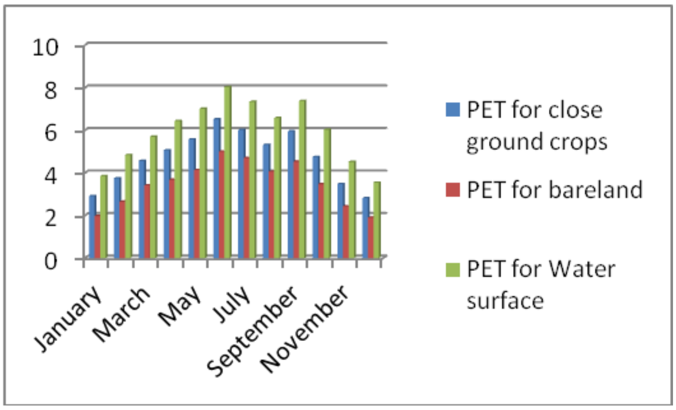

Figure No.5: Comparative monthly PET variation of all three situations

V CONCLUSION

The bar chart drawn for the three different conditions depicted i.e. close ground crops, bare land and water surface. In Figure No.2, 3, 4 and 5 represents the monthly variation of PET throughout the year. The chart shows clearly the increasing trend of PET from January to June and there after decreasing trend up to December with highest value for the month of June. With 6.52 mm/day for the close ground crop, 5 mm/day for the bare land and 8.03 mm/day for the water surface. The reason for highest PET of the water surface is due to free evaporation from the surface water bodies such as lake and dam reservoirs. This indicates that there is higher need to manage the surface water resource and utilise the same for consumptive purposes.

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BIOGRAPHY

Dr Ram Karan Singh is presently Professor in the Civil Engineering Department, King Khalid University in the Kingdom of Saudi Arabia. He has over **22 years** of teaching, research, administrative, and consultancy experience in top institutions/universities in India (14 years) and abroad (8 years). He held various administrative positions such as **Dean** of Research and Development, **Head** of the department and **Head** of the Research, Development and Industrial Liaison in various universities during the tenure of his work. He is a member of various national and international academic, research and administrative committees.
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