Estimation of Potential Evapo-Transpiration of Asir Region, Kingdom of Saudi Arabia: Considering Climate Variability

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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 Asir region located in southwestern part of Kingdom Of Saudi Arabia 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 Asir region other than built up areas. The result obtained will help the water resource management of the Asir region 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-**Evapotranspiration, Climate Variability,Penman method,Climate Change**

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

Asir region is located in the southwestern part of the Kingdom of Saudi Arabia between latitude 17:27-21:00 and longitude 41:23-44:33. Its population exceeds one and a half million, representing 10% of the kingdom population and one quarter of the Kingdom's total area. The region is a mountainous area and is divided into 3 different topographical zones based on geographical characteristics as follows. In present research three zones namely i.e. Abha,Bishah and Khamis Mushayt are identified and the meteriological data such as sun shine hours, temperature,precipitation,humidity,solar radiation and wind velocity has been utilised.These data has been procured by the web portal ofmetreological department of the kingdom of Saudi Arabia.

Fig. 1. Map of Asir region in the 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:

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

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 0.52A
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

TABLE 1: INPUT DATA OF THE WEATHER PARAMETERS USED IN PENMAN EQUATION OF ABHA IN ASIR REGION

Month	**Avg. Tem ^{0}C**	**R.H %**	**Wind speed Km/h**	**N-Max sunshine hours**	**n**	**Solar radiation-mm/day**
JAN	13.3	70	311.9	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 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

The input data used for the computation of potential evapotranspiration is shown in Table 1-3. The data was obtained from the web portal of the Meteorological department of the Kingdom of the Saudi Arabia.

TABLE 2: INPUT DATA OF THE WEATHER PARAMETERS USED IN PENMAN EQUATION OF KHAMIS IN ASIR REGION

Month	**Avg. Tem ^{0}C**	**R. H %**	**Wind speed Km/h**	**N-Max sunshine hours**	**n**	**Solar radiation-mm/day**
JAN	14.2	65	267.3	11	9	11
FEB	15.9	62	311.9	11.6	9.6	12
MAR	17.8	58	311.9	12	8.2	14.2
APR	19.5	55	267.3	12.5	9	15.1
MAY	22.4	47	222.8	13	8.6	15.5
JUN	24.4	38	267.3	13.2	10	15
JUL	24.2	44	267.3	13.1	8	15
AUG	23.8	49	267.3	12.7	8	15.1
SEP	23.1	36	267.3	12.4	10	14.6
OCT	19.7	38	267.3	11.7	10.1	13
NOV	17.2	55	178.2	11.3	8.5	12
DEC	14.9	62	222.8	11	9	11.1

Source: Web portal Meteorological department Kingdom of Saudi Arabia

TABLE 3: INPUT DATA OF THE WEATHER PARAMETERS USED IN PENMAN EQUATION OF BISHA IN ASIR REGION

Month	**Avg. Tem ^{0}C**	**R.H %**	**Wind speed Km/h**	**N-Max sunshine hours**	**n**	**Solar radiation-mm/day**
JAN	14.2	65	267.3	11	9	11
FEB	15.9	62	311.9	11.6	9.6	12
MAR	17.8	58	311.9	12	8.2	14.2
APR	19.5	55	267.3	12.5	9	15.1
MAY	22.4	47	222.8	13	8.6	15.5
JUN	24.4	38	267.3	13.2	10	15
JUL	24.2	44	267.3	13.1	8	15
AUG	23.8	49	267.3	12.7	8	15.1
SEP	23.1	36	267.3	12.4	10	14.6
OCT	19.7	38	267.3	11.7	10.1	13
NOV	17.2	55	178.2	11.3	8.5	12
DEC	14.9	62	222.8	11	9	11.1

Source: Web portal Meteorological department Kingdom of Saudi Arabia

VI. RESULTS

The result obtained using the method above is plotted and reported from Figure. no 2 to 4 for three different cases i.e. close ground crops, bare land and water surface respectively excluding the built up area of the Asir Region. The regression analysis was done for nine different combination of three situations which is plotted from Figure no-5 to 13.

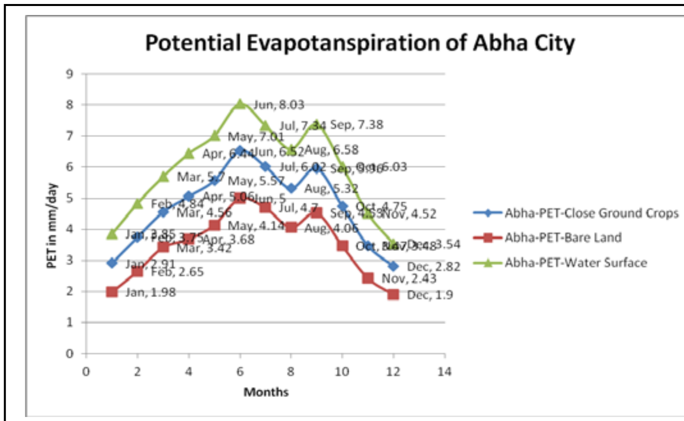

Fig. 2. Comparative monthly PET variation of three situations of Abha in Asir Region.

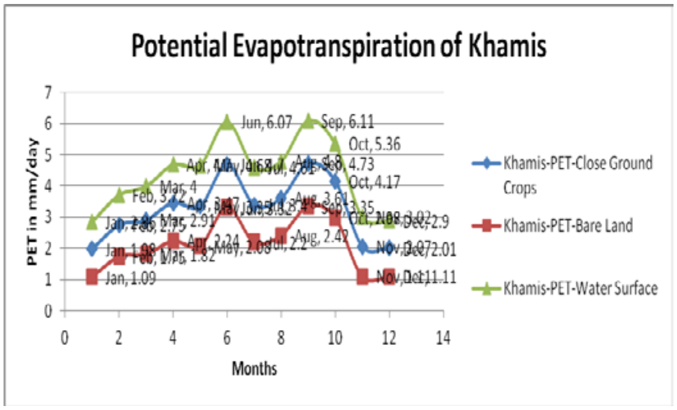

Fig. 3. Comparative monthly PET variation of three situations of Khamis in Asir Region

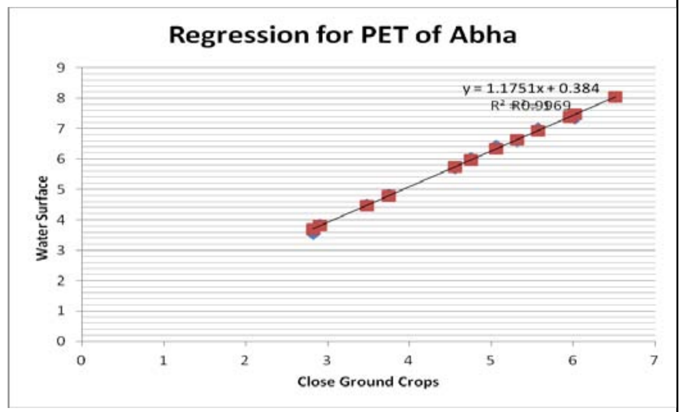

Fig. 6: Regression analysis results of PET of Abha in Asir region

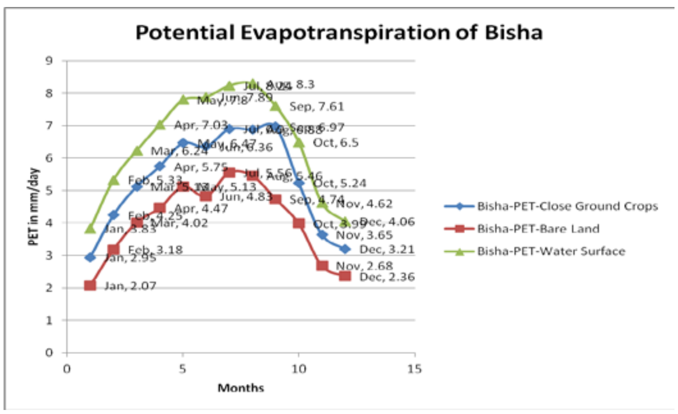

Fig. 4. Comparative monthly PET variation of three situations of Bisha in Asir Region.

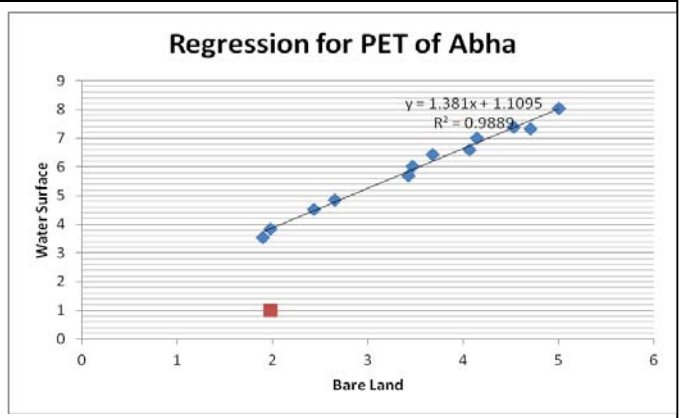

Fig. 7: Regression analysis results of PET of Abha in Asir region

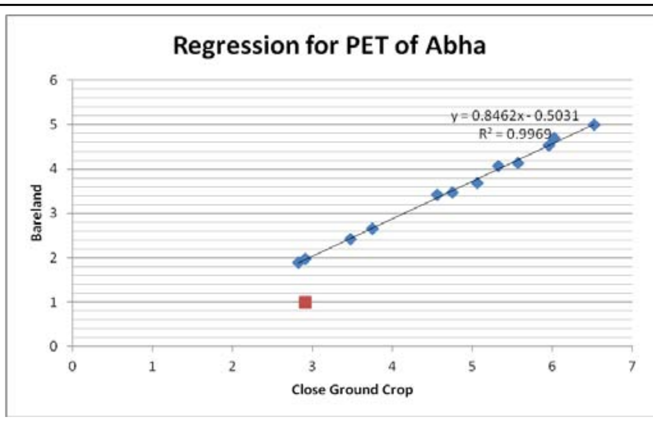

Fig. 5: Regression analysis results of PET of Abha in Asir region

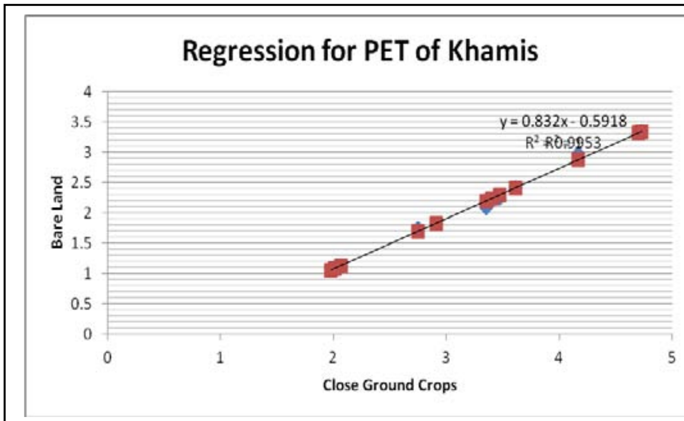

Fig. 8: Regression analysis results of PET of Khamis in Asir region

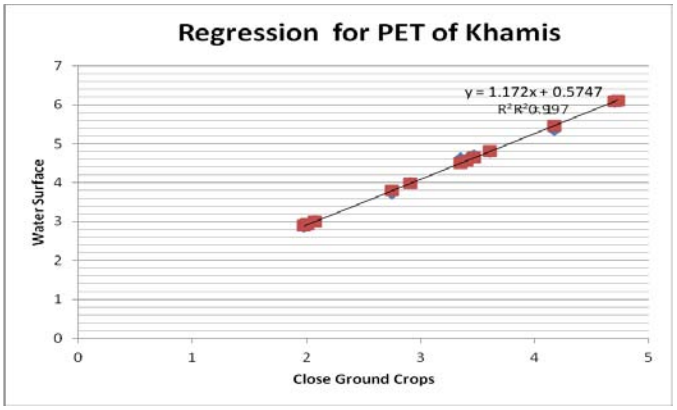

Fig. 9: Regression analysis results of PET of Khamis in Asir region.

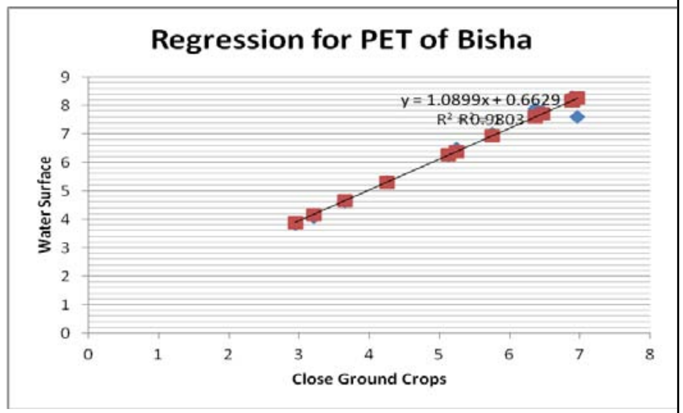

Fig. 12: Regression analysis results of PET of Bisha in Asir region

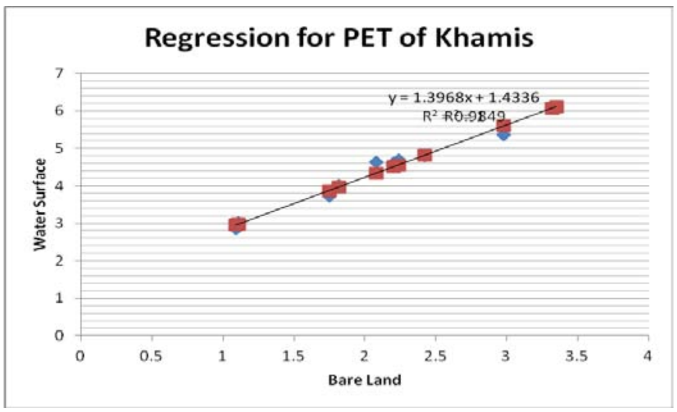

Fig. 10: Regression analysis results of PET of Khamis in Asir region

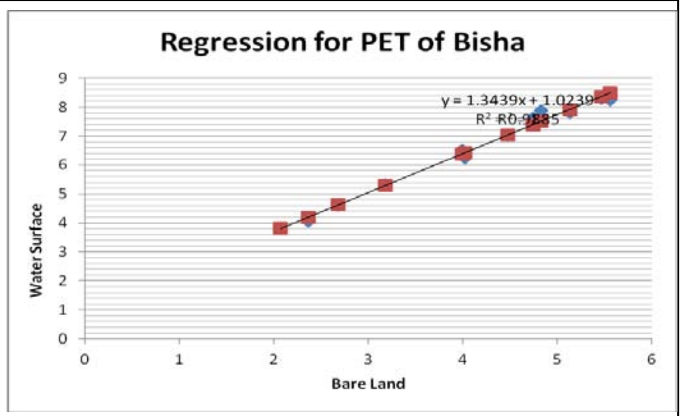

Fig. 13: Regression analysis results of PET of Bisha in Asir region

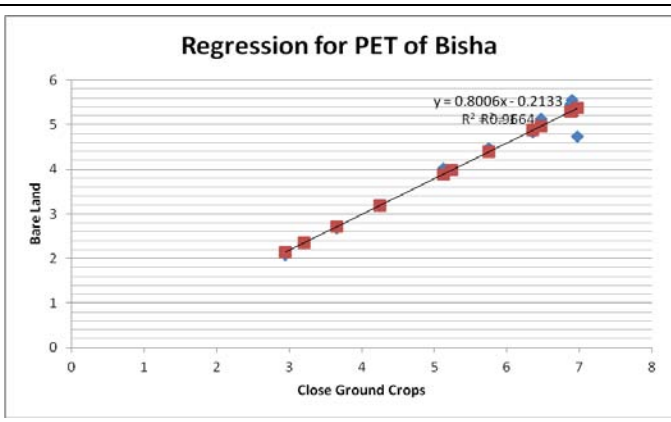

Fig. 11: Regression analysis results of PET of Bisha in Asir region
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V. CONCLUSION

The results plotted for the three different conditions depicted i.e. close ground crops, bare land and water surface. In Figure No.2, 3 and 4 represents the monthly variation of PET throughout the year. The graph 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 in Abha, with 4.73 mm/day for the close ground crop, 3.35 mm/day for the bare land and 6.11 mm/day for the water surface in Khamis, with 6.90 mm/day for the close ground crop, 5.56 mm/day for the bare land and 8.30 mm/day for the water surface in Bisha covering full Asir region of the Kingdom of Saudi Arabia, 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.Also regression analysis is done for nine different combinations of three situations selected and a very high correlation has been found ranging from 0.98-0.99.

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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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Mr. Saiful Islam is presently Lecturer in the Civil Engineering Department, King Khalid University in the Kingdom of Saudi Arabia. He has over **5 years** of teaching, research, experiance. He did his B.Tech degree from Zakir Hussain College of Engineering, A.M.U, Aligarh. He has completed his M.Tech degree from Indian Institute of Technology, Roorkee.

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