SENSITIVITY ANALYSIS OF EVAPOTRANSPIRATION FOR ROORKEE, UTTARAKHAND, INDIA

[1]Aparajita Singh [2] A.R. Senthil Kumar [3]R.M. Singh [4]V.K. Triapthi [5]Aradhana Thakur
[1]Research scholar [2]Scientist E [3]Professor [4]Asst. Professor [5]Research Scholar
[1,3,4,5] Department of Farm Engineering, Institute of Agricultural Science, Banaras Hindu University, Varanasi, UP, 221005
[2]National Institute of Hydrology, Roorkee, Uttarakhand

Abstracts-The need of existing water allocation in a sustainable manner with meeting the needs of the projected population growth, initiated to assess the consumptive use or evapotranspiration (ET), which ultimately determines the irrigation demand. Its estimation is very much essential in the fields associated with water resources management. ET denotes evaporative nature of the atmosphere and depends on climatic parameters like solar radiation, temperature, relative humidity, wind speed etc. Sensitivity analysis is important to understand the relative importance of climatic variables to the variation of the evapotranspiration (ET). It is done to acquire a better understanding of the climatological parameters, which particularly indicates the physical meaning of each climatic parameter used in the ET estimation. In the present study, a graphical attempt was made to predict the average percentage change in responses of ET with respect to the percentage change of the various climatic variables, obtained at NIH Observatory, Roorkee. A historical monthly dataset of average temperature, relative humidity, solar radiation, sunshine hour from 1987-2013 were used in this analysis. The graphical sensitivity analysis based on sensitivity index was done using two evaoptranspiration methods i.e., Thornthwaite and Turc method and a comparison was made among them. The results of the study showed that monthly sensitivity exhibited large fluctuations during the growing season and solar radiation was the most sensitive variable in general for the NIH, followed by mean temperature and sunshine hours. It also showed that the influence of the climatic variables to ET, is not the same for each period. Solar radiation and mean temperature are the main parameters that affect ET.

Keywords- Sensitivity, ET, Turc method, Thornthwaite method.

I. INTRODUCTION

Evapotranspiration (ET) is an essential component of the hydrologic cycle in semi-arid regions. It denotes the evaporative demand of the atmosphere in a given location and time. Most of the precipitation about 62% falling on land is evapotranspirated (Ambas and Baltas, 2012). Estimation of ET significantly affects the water balance of the nature. Therefore, its estimation is essential for water availability, plant growth, irrigations efficiency, water resources management and many more. Accurate ET estimation is beneficial for irrigation scheduling as well as in the area of water resources management. Several empirical methods have developed across the globe to derive ET. Among all these methods, the Penman–Monteith method which was recommended by the Food and Agriculture Organization of the U.N. (FAO) is the most commonly used method for calculating reference evapotranspiration wherever the required input data i.e. temperature, relative humidity, solar radiation, wind speed are available (e.g., Ampas, 2010). The other widely used methods for ET estimation are the Blaney and Criddle method (Doorenbos and Pruitt, 1977), the FAO 24 Makkink method, the Hargreaves method, Turc, Thornthwaite method etc.

Global warming and various associated changes in climate are may affects the climatic parameters to varying level. This in turn would affect the ET. Sensitivity analysis carried to evaluate the role of each climatic parameter which is required for the computation of ET. Sensitivity analysis defined as the important stage to evaluate the environmental models. The current research scenario demands the need to assess the physical meaning of model parameters and their relative influence on the meteorological variables. In simple words, sensitivity analysis was done to evaluate the impact of the change of one parameter to another (McCuen, 1973). In past several studies was done to assess the parameter sensitivity to estimated evapotranspiration using sensitivity coefficients which were calculated for several independent variables as meteorological parameters, physiological parameters and climatic conditions. The comparison of sensitivity coefficients has showed the relative importance of each variable. Saxton (1975) from their research concluded that the most important variable for the calculation of ETo, during summer is solar radiation whereas in autumn and spring the most important variable is the aerodynamic variable. Coleman and DeCoursey (1976) from their study concluded that the most important parameter at the annual scale is relative humidity whereas during summer both temperature and solar radiation are the most important variables while relative humidity is more important during winter. They also concluded that wind speed has very small importance at the annual scale. Babajimopoulos et al. (1992) conclude that temperature and solar radiation are the most important variables in the summer whereas the most important parameter in the winter is relative humidity. Gong et al. (2006) evaluated sensitivity coefficients for the Yangtze River basin and indicated their large spatial variability. Irmak et al. (2006) evaluated sensitivity coefficients for areas under different climatic characteristics. Their results showed the large spatial variability and the authors concluded that for areas with strong and dry winds wind speed was the most important variable.

In the present study, an attempt was developed to carry out sensitivity analysis for evapotranspiration. In this, the parameters which sensitive to the estimated ET based on two methods i.e. Thornthwaite and Turc method has been assessed and evaluated the impact of the change in the measured climatic variables to the estimated ET. The relative influence of each climatic parameter to the estimated ET has been compared. The sensitivity analysis is based on the comparison of the influence of the change in independent parameters to dependent parameter i.e., ET. This study was carried using climatic parameters as inputs for NIH, Roorkee (Uttarakhand), India. Data from January 1987 to December 2013 was used for sensitivity analysis.

II. MATERIALS AND METHODS

2.1 Study area

Roorkee is located in Hardwar district at $29^0$51' N and 77^0 53' E on the south bank of Solani River. The Upper Ganga Canal is the most important features and adds beauty to the city. Running from north to south, it divides the city in two distinct parts. City is located about 274 Meters above mean sea level and receives the average annual rainfall of 1068 mm, average Monsoon Rainfall of 878 mm and having average Max. Temperature 40 ^{0}C and average Min. Temperature 2^0C. Max. Humidity 100 %, Average Min. Humidity 30 %, Average Annual Potential ET 1340 mm, Average Annual Wind Speed 4.9 m/s . Due to its location away from any major water body and its proximity to the Himalayas, Roorkee has an extreme and erratic continental climate. Temperature begins to rise from March (29.1°C) and reaches to its maximum in June (44°C). The monsoon season starts in July and goes on until October, with torrential rainfall, due to the blocking of the monsoon clouds by the Himalayas. The potential evapotranspiration is maximum in the month of May 198.9 mm and minimum 38.5 mm in the month of December.

2.2 Data Availability

The data for sensitivity analysis was obtained from NIH observatory, Roorkee. The monthly data of relative humidity, solar radiation, sunshine hours, maximum temperature, minimum temperature and mean temperature were collected from January 1987 to December 2013 and presented in figure1.

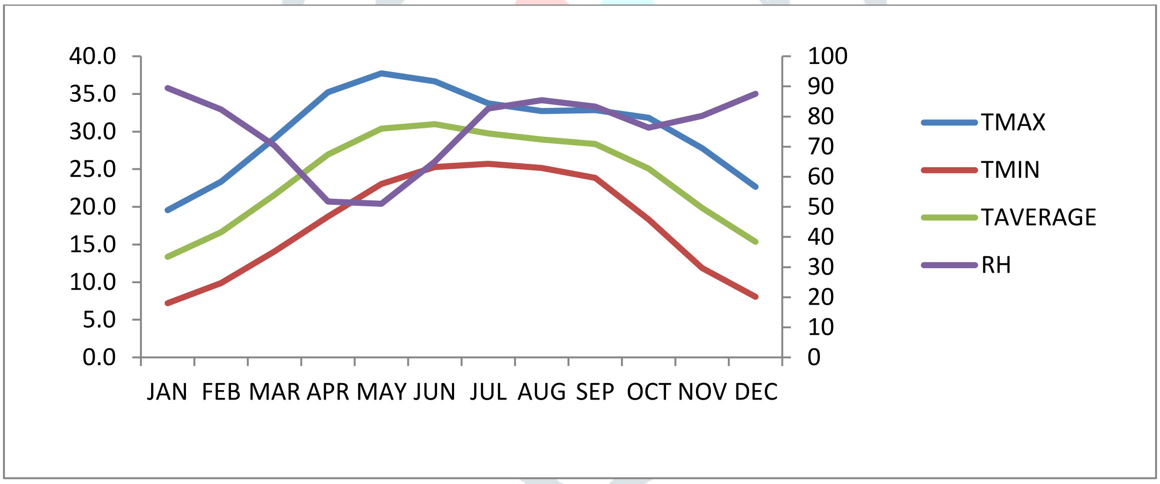

Figure 1- Monthly maximum, minimum, average temperature and relative humidity from 1987-2013 for sensitivity analysis of Evapotranspiration

2.3 Evapotranspiration

In hydrology and irrigation practice, evaporation and transpiration process considered one heading i.e., evapotranspiration (ET).The loss of water by evapotranspiration is term as consumptive use. For given set of atmospheric conditions, evapotranspiration depends on the availability of water. Potential evapotranspiration (PET) is the evapotranspiration resulting when sufficient moisture is available to meet the need of fully area covering vegetation. PET critically no longer depends on soil and plant factor; in fact it only depends on climatic variables.

The global population increase and higher irrigation demand in agriculture initiates the need to manage the available freshwater wisely which brought ET as one of the critical area to research in the hydrology field. In the past years, with many research works, various methods were developed to estimate ET. ET expresses the evaporating power of the atmosphere at a specific location and time of the year (A.S.C.E., 2005). Numerous empirical methods have been developed over the last 50 years to estimate ET using different climatic variables.

i. Thornthwaite Method

Thornthwaite correlated mean monthly temperature with ET as determined by east-central United States water balance studies. The Thornthwaite equation is given in equation 2.2

$$ET_{0K} = \frac{16N_K}{360}\left[\left(\frac{10K_T}{\sum_{K=1}^{12} 0.2T_K^{\,1.514}}\right)^{0.016\sum_{K=1}^{12} 0.2T_K^{\,1.514}+0.5}\right] \quad (2.1)$$

Where, ET_{0K} is potential evapotranspiration in the K_{th} month (mm); N_K is the maximum possible duration of sunshine in the K_{th} month (hours); T_K is the mean air temperature in the K_{th} month (°C) and k = 1, 2, ….. , 12.

ii. Turc Method:

Turc developed an equation for potential ET under general climatic conditions of Western Europe. He proposed the following equations for two humidity conditions.

When RH_{mean}> 50%,

$$ET_0 = 0.013\frac{T_{mean}}{T_{mean}+15}(R_S'+50)\frac{1}{\lambda} \quad (2.2)$$

When RH_{mean}≤ 50%,

$$ET_0 = 0.013\frac{T_{mean}}{T_{mean}+15}(R_S'+50)\frac{1}{\lambda}\left(1+\left(\frac{50-RH_{mean}}{70}\right)\right) \quad (2.3)$$

Where, T_{mean} is mean air temperature (ºC), RH_{mean} is mean relative humidity (%), R_s' is solar radiation (cal/cm^2/day). If R_s (MJ/m^2/day) is known, it can be calculated as

$$R_S' = \frac{R_S}{0.041869} \quad (2.4)$$

λ is the latent heat of vaporization (MJ/kg). It can be estimated using mean air temperature as

$$\lambda = 2.501 - 0.002361T_{mean} \quad (2.5)$$

2.4 Sensitivity analysis

The mathematical model of a dependent variable ***{y = f(x₁, x₂, x₃…. xₙ)}*** is formed by means of model parameters/independent variables (***x₁, x₂, x₃…. xₙ***) that define the underlying processes. Therefore, there exists a need to determine the parameters that are most influential on model outcome and mostly correlated with model output. Oftentimes, sensitivity analysis is conducted to identify the influential parameter sets. In simple words, sensitivity analysis was done to investigate the effect of change of one factor over another (McCuen, 1973).

A simple but practical way of presenting a sensitivity analysis is to plot relative changes of a dependent variable against relative changes of an independent variables as a curve (e.g., McKenney and Rosenberg, 1993; Singh and Xu, 1997; Goyal, 2004), denoted as the ‘‘sensitivity curve method’’.

For multi-variable models (e.g., the P–M method), different variables have different dimensions and different ranges of values, which makes it difficult to compare the sensitivity by partial derivatives. Consequently, the partial derivative is transformed into a non dimensional form (e.g., Beven, 1979). A number of sensitivity coefficients can be defined based on dimensionless values of the ET change for different purposes of sensitivity analysis (Gong *et al.*, 2006). The dimensionless values of sensitivity coefficients for different meteorological parameters allow the comparison between them. Saxton (1975) defined dimensionless sensitivity coefficients for each meteorological variable based on equation 2.7

$$K_{s_p} = \frac{\delta M_P}{\delta p M} \quad (2.6)$$

Where p is the examined independent variable or parameter and M is the modeled value. This coefficient shows the percentage of change in ET caused by the percentage change of a meteorological variable. The calculation of the partial derivative of ET to a variable depends on all the meteorological variables and its value depends on them.

However, Equation (2.6) is sensitive to the magnitudes of ET and p. In particular, the relative sensitivity coefficient K_{S_p} may not be a good indication of the significance of the variable if either: 1) the value of ET or the value of the parameter tends to zero independently or 2) the range of values taken by p is small in relation to its magnitude (Beven, 1979), Coleman and DeCoursey (1976) provided a more meaningful coefficient when comparing variables some of which may have a range in variability quite different from their mean value, hence the bias caused by the method of measurement is eliminated. The coefficient is given by equation 2.7

$$K_{S_P} = \frac{\delta Mp - p_{mean}}{\delta pM} \quad (2.7)$$

Where p_{mean} is the minimum observed value of the independent variable. Babajimopoulos et al. (1992) estimated the influence of the meteorological variables to ET changing by 10, 20 and 30% the meteorological variables and assessing its impact on the calculated ET. However, in this case the variation of a parameter could significantly influence the sensitivity of the parameters to the model. More recently, Ampas (2010) proposed the use of standard deviation and presented a new sensitivity coefficient:

$$K_{S_P} = \frac{\delta M \sigma_p}{\delta pM} \quad (2.8)$$

Where σ_p is the standard deviation of the meteorological variable.

2.5 Sensitivity Index

Sensitivity index (Φ_i) is calculated using Equation (2.9) by varying the parameter from its minimum to its maximum value.

$$\Phi_i = \frac{ET_{max} - ET_0}{ET_0} \quad (2.9)$$

Where, ET_{max} = Increase ET with % increase of independent variable *i*, ET_0 = original ET, *i* = independent variable

III. RESULTS AND DISCUSSION

The sensitivity analysis has been performed for all of the meteorological parameters that are needed in each method. The sensitivity analysis of estimated ET calculated from Thornthwaite method was examined for mean temperature and sunshine hours. The estimated ET calculated from Turc method was examined for mean temperature and solar radiation.

3.1 Sensitivity analysis by Thornthwaite method

According to Thornthwaite method, ET depends upon two independent variables i,e mean temperature and sunshine hours. So by increasing the values of the one of the independent variables to 5%, 10%, 15%, 20%, 25% keeping other constant, the increased values of ET and average sensitivity index Φ_i at 5%, 10%, 15%, 20%, 25% are obtained and presented in table 3.1, table 3.2

Table- 3.1 Sensitivity index Φ_T and % increase in ET with % increase in temperature (Thornthwaite method)

	ET (T 5%)	$\Phi_{5\%}$	ET (T10%)	$\Phi_{10\%}$	ET (T15%)	$\Phi_{15\%}$	ET (T20%)	$\Phi_{20\%}$	ET (T25%)	$\Phi_{25\%}$	ET (0%)
JAN	0.125	-0.065	0.116	-0.130	0.108	-0.194	0.099	-0.258	0.091	-0.319	0.134
FEB	0.472	-0.032	0.456	-0.066	0.438	-0.102	0.419	-0.141	0.399	-0.181	0.488
MAR	1.140	0.010	1.149	0.018	1.154	0.023	1.155	0.024	1.154	0.022	1.128
APR	2.530	0.047	2.644	0.095	2.758	0.142	2.870	0.188	2.980	0.234	2.415
MAY	3.989	0.068	4.253	0.139	4.527	0.212	4.810	0.288	5.102	0.366	3.735
JUN	3.276	0.071	3.504	0.146	3.742	0.223	3.990	0.304	4.246	0.388	3.059
JUL	2.491	0.064	2.646	0.130	2.806	0.199	2.971	0.269	3.139	0.341	2.341
AUG	1.687	0.059	1.784	0.120	1.883	0.183	1.984	0.246	2.087	0.311	1.592
SEPT	2.320	0.056	2.445	0.113	2.572	0.171	2.701	0.229	2.830	0.288	2.197
OCT	1.825	0.035	1.885	0.069	1.943	0.102	1.997	0.132	2.047	0.161	1.763
NOV	0.850	-0.003	0.845	-0.010	0.837	-0.020	0.826	-0.032	0.812	-0.048	0.853
DEC	0.273	-0.044	0.260	-0.089	0.246	-0.137	0.232	-0.185	0.218	-0.234	0.285
Avg Φ_T		0.022		0.045		0.067		0.089		0.111	

*Avg Φ_T =Average of the ratio of difference of increase ET with increase of independent variable and original ET to original ET, *$\Phi_{5\%}$, $\Phi_{10\%}$, $\Phi_{15\%}$, $\Phi_{20\%}$, $\Phi_{25\%}$ = Ratio of increase ET with increase of temperature to 5%, 10%, 15%, 20% , 25% and original ET to original ET, *ET (T5%), ET (T10%)…….ET(T25%) =Increase in ET with percent increase in temperature to 5%, 10%.....25% respectively., ET (0%) = original ET

Table- 3.2 Sensitivity index Φ_S and % increase in ET with % increase in Sunshine hour (Thornthwaite method)

	ET (S5%)	$\Phi_{5\%}$	ET (S10%)	$\Phi_{10\%}$	ET (S15%)	$\Phi_{15\%}$	ET (S20%)	$\Phi_{20\%}$	ET (S25%)	$\Phi_{25\%}$	ET (0%)
FEB	0.512	0.050	0.537	0.100	0.561	0.150	0.585	0.200	0.610	0.250	0.488
MAR	1.185	0.050	1.241	0.100	1.298	0.150	1.354	0.200	1.410	0.250	1.128
APR	2.536	0.050	2.657	0.100	2.778	0.150	2.898	0.200	3.019	0.250	2.415
MAY	3.922	0.050	4.109	0.100	4.296	0.150	4.482	0.200	4.669	0.250	3.735
JUN	3.212	0.050	3.364	0.100	3.517	0.150	3.670	0.200	3.823	0.250	3.059
JUL	2.458	0.050	2.575	0.100	2.692	0.150	2.809	0.200	2.926	0.250	2.341
AUG	1.672	0.050	1.752	0.100	1.831	0.150	1.911	0.200	1.990	0.250	1.592
SEPT	2.307	0.050	2.417	0.100	2.527	0.150	2.637	0.200	2.747	0.250	2.197
OCT	1.852	0.050	1.940	0.100	2.028	0.150	2.116	0.200	2.204	0.250	1.763
NOV	0.896	0.050	0.939	0.100	0.981	0.150	1.024	0.200	1.067	0.250	0.853
DEC	0.299	0.050	0.314	0.100	0.328	0.150	0.342	0.200	0.356	0.250	0.285
Avg Φ_S		0.050		0.100		0.150		0.200		0.250	

*Avg Φ_S =Average of the ratio of difference of increase ET with increase of independent variable and original ET to original ET, *$\Phi_{5\%}$, $\Phi_{10\%}$, $\Phi_{15\%}$, $\Phi_{20\%}$, $\Phi_{25\%}$ = Ratio of increase ET with increase of sunshine hour to 5%, 10%, 15%, 20% , 25% and original ET to original ET, *ET (S5%), ET (S10%)…….ET(S25%) =Increase in ET with percent increase in sunshine hour to 5%, 10%.....25% respectively., ET (0%) = original ET

3.2 Sensitivity analysis by Turc Method:
According to Turc Method, ET depend upon two independent variables i,e mean temperature and solar radiation, so by increasing the values of the one of the independent variables to 5%, 10%, 15% ,20%, 25% keeping other constant ,we get the values which are given in table 3.3 and table 3.4

Table- 3.3 Sensitivity index Φ_T and % increase in ET with % increase in temperature (Turc method)

	ET (T5%)	$\Phi_{5\%}$	ET (T10%)	$\Phi_{10\%}$	ET (T15%)	$\Phi_{15\%}$	ET (T20%)	$\Phi_{20\%}$	ET (T25%)	$\Phi_{25\%}$	ET (0%)
JAN	1.394	0.026	1.428	0.052	1.461	0.076	1.493	0.099	1.523	0.122	1.358
FEB	1.888	0.024	1.930	0.047	1.970	0.069	2.009	0.089	2.045	0.109	1.844
MAR	2.536	0.021	2.585	0.041	2.632	0.060	2.677	0.078	2.719	0.095	2.483
APR	3.198	0.019	3.253	0.036	3.306	0.053	3.356	0.069	3.403	0.084	3.139
MAY	3.596	0.017	3.654	0.034	3.710	0.050	3.762	0.065	3.812	0.079	3.534
JUN	3.727	0.017	3.787	0.034	3.844	0.049	3.898	0.064	3.949	0.078	3.664
JUL	3.611	0.018	3.670	0.034	3.726	0.050	3.780	0.065	3.831	0.080	3.548
AUG	3.387	0.018	3.444	0.035	3.497	0.051	3.548	0.066	3.596	0.081	3.327
SEPT	2.987	0.018	3.038	0.035	3.085	0.052	3.131	0.067	3.174	0.082	2.934
OCT	2.416	0.019	2.459	0.038	2.500	0.055	2.540	0.072	2.577	0.087	2.370
NOV	1.796	0.022	1.832	0.043	1.867	0.063	1.900	0.081	1.932	0.099	1.757
DEC	1.401	0.025	1.434	0.049	1.465	0.071	1.494	0.093	1.523	0.114	1.367
Avg Φ_T		0.020		0.040		0.058		0.076		0.092	

*Avg Φ_T =Average of the ratio of difference of increase ET with increase of independent variable and original ET to original ET, *$\Phi_{5\%}$, $\Phi_{10\%}$, $\Phi_{15\%}$, $\Phi_{20\%}$, $\Phi_{25\%}$ = Ratio of increase ET with increase of temperature to 5%, 10%, 15%, 20% , 25% and original ET to original ET, *ET (T5%), ET (T10%)…….ET(T25%) =Increase in ET with percent increase in temperature to 5%, 10%.....25% respectively., ET (0%) = original ET

Table-3.4 Sensitivity index Φ_R and % increase in ET with % increase in solar radiation (Turc Method)

	ET (R5%)	$\Phi_{5\%}$	ET (R10%)	$\Phi_{10\%}$	ET (R15%)	$\Phi_{15\%}$	ET (R20%)	$\Phi_{20\%}$	ET (R25%)	$\Phi_{25\%}$	ET (0%)
JAN	1.419	0.045	1.481	0.091	1.543	0.136	1.604	0.182	1.666	0.227	1.358
FEB	1.929	0.046	2.014	0.092	2.100	0.139	2.185	0.185	2.270	0.231	1.844
MAR	2.600	0.047	2.716	0.094	2.833	0.141	2.949	0.187	3.065	0.234	2.483
APR	3.288	0.047	3.436	0.095	3.584	0.142	3.733	0.189	3.881	0.236	3.139
MAY	3.702	0.047	3.870	0.095	4.037	0.142	4.205	0.190	4.373	0.237	3.534
JUN	3.838	0.048	4.012	0.095	4.186	0.143	4.361	0.190	4.535	0.238	3.664
JUL	3.716	0.047	3.885	0.095	4.053	0.142	4.222	0.190	4.391	0.237	3.548
AUG	3.485	0.047	3.643	0.095	3.800	0.142	3.958	0.189	4.115	0.237	3.327
SEPT	3.072	0.047	3.210	0.094	3.348	0.141	3.486	0.188	3.624	0.235	2.934
OCT	2.480	0.046	2.590	0.093	2.700	0.139	2.810	0.186	2.921	0.232	2.370
NOV	1.838	0.046	1.918	0.091	1.998	0.137	2.079	0.183	2.159	0.229	1.757
DEC	1.429	0.045	1.490	0.090	1.552	0.135	1.614	0.180	1.676	0.226	1.367
Φ_R		0.047		0.093		0.140		0.187		0.233	

*Avg Φ_R =Average of the ratio of difference of increase ET with increase of independent variable and original ET to original ET, *$\Phi_{5\%}$, $\Phi_{10\%}$, $\Phi_{15\%}$, $\Phi_{20\%}$, $\Phi_{25\%}$ = Ratio of increase ET with increase of solar radiation to 5%, 10%, 15%, 20% , 25% and original ET to original ET, *ET (R5%), ET (R10%)…….ET(R25%) =Increase in ET with percent increase in solar radiation to 5%, 10%.....25% respectively., ET (0%) = original ET

Table 3.5 - The comparison between average sensitivity index (Φ_i) with percent increase in respective independent variables (i,e temperature, sunshine, solar radiation) in Thornthwaite and Turc Method

% increase in independent variables	**Avg Φ_T (Thornthwaite Method)**	**Avg Φ_S (Thornthwaite Method)**	**Avg Φ_T (Turc Method)**	**Avg Φ_R (Turc Method)**
0	0	0	0	0
5%	0.022	0.050	0.020	0.047
10%	0.045	0.100	0.040	0.093
15%	0.067	0.150	0.058	0.140
20%	0.089	0.200	0.076	0.187
25%	0.111	0.250	0.092	0.233

*% = Percentage, Avg = Average, ET= Evapotranspiration, Φ_i = Average sensitivity index with respect to independent variables i.e., Φ_i = Φ_T, Φ_S, Φ_R

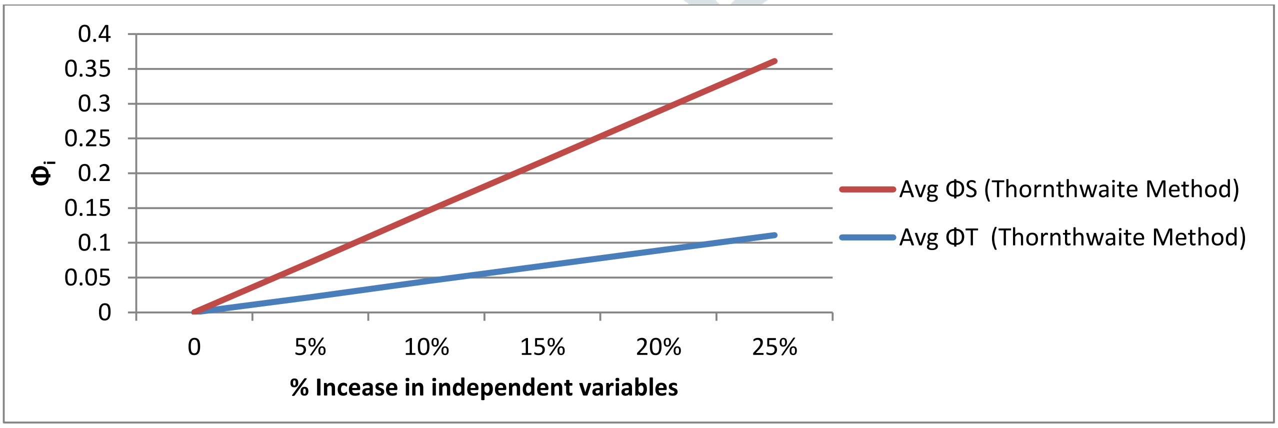

Figure 2- Variation of average sensitivity index (Φ_i) with percent increase in independent variables i.e., temperature (T), sunshine hour (S) to 5%, 10%.....25% in Thornthwaite method.

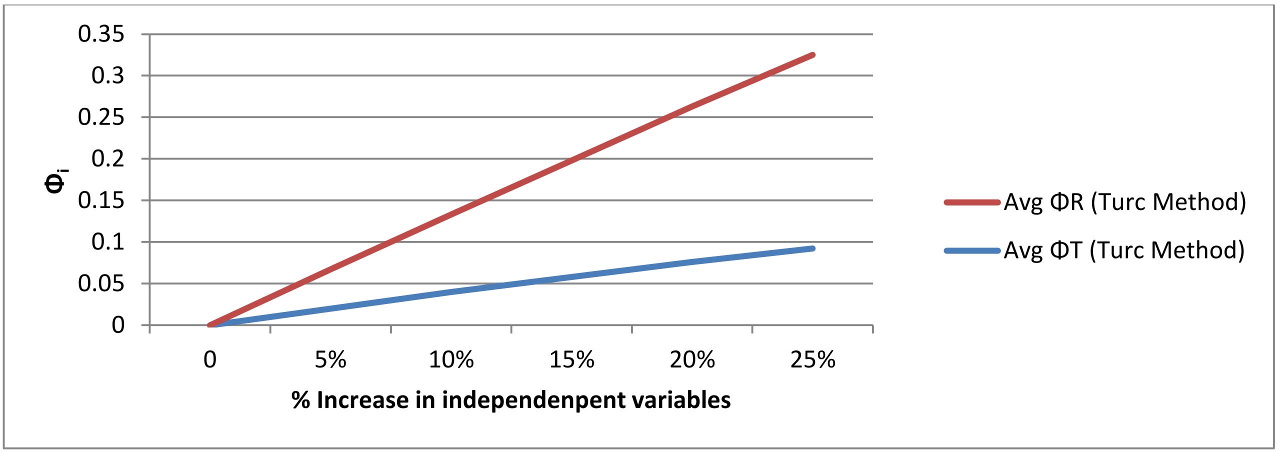

Figure 3- Variation of average sensitivity index (Φ_i) with percent increase in independent variables i.e., temperature (T), solar radiation (R) to 5%, 10%.....25% in Turc method.

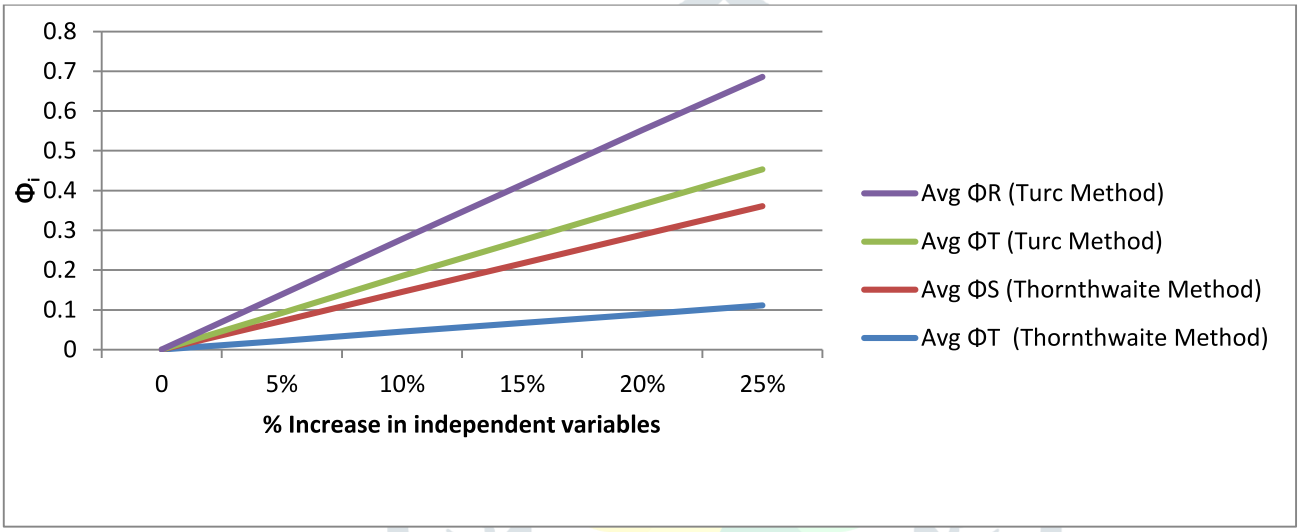

Figure 4- Comparison between average sensitivity index (Φ_i) with % increase in independent variables i.e., temperature, solar radiation, sunshine in both Thornthwaite method and Turc method

IV. CONCLUSIONS

Sensitivity analysis of monthly evapotranspiration (ET) was conducted on principal climatic variables, namely mean temperature, sunshine hours and solar radiation using monthly data 1987-2013 of NIH Roorkee of Uttarakhand state. The analysis revealed that monthly ET was more affected by solar radiation followed by sunshine hours and mean temperature. The slopes of the graph that are obtained during the sensitivity analysis by Thornthwaite method and Turc method by changing the one independent variables (i,e sunshine hours, average temperature, relative humidity, solar radiation) while keeping others constant indicates the impacts of sensitivity of independent variables on the ET. The slopes of the graph clearly indicates that while during the sensitivity analysis by Thornthwaite ,sunshine hours has more impact than that of other independent parameters like mean temperature whereas during the sensitivity analysis by Turc method ,solar radiation has more impacts on evapotranspiration. On comparing the slopes of graph made between sensitivity analysis during the Thornthwaite method and Turc method, we concluded that solar radiation is the most important independent parameter that affects the evapotranspiration followed by average temperature and sunshine hours.

REFERENCES

A.S.C.E. Standardization of Reference Evapotranspiration Task Committee, (2005). The ASCE standardized reference evapotranspiration equation. Environmental and Water Resources Institute of the American Society of Civil Engineers.

Ambas V T and Baltas E 2012 Sensitivity analysis of different evapotranspiration methods using a new sensitivity coefficient; Global NEST J. 14(3) 335–343.

Ampas V., (2010). Research and estimation of meteorological parameters with direct impact on agriculture. Ph.D. Thesis. Aristotle University of Thessaloniki, Greece.

Babajimopoulos Ch., Antonopoulos B., Grigoriadis D. and Ilias A., (1992). Sensitivity analysis of the Penman method. proceedings of 5th conference of H.Y.U., p. 132-140.

Beven K., (1979). A sensitivity analysis of the penman Monteith actual evapotranspiration estimates, Journal of Hydrology, 44, 169-190.

Coleman G. and DeCoursey G.D., (1976). Sensitivity analysis applied to some evaporation and evapotranspiration models, Water Resour. Res., 12(5), 873-879.

Doorenbos J. and Pruitt W.O., (1977). Guidelines for predicting crop water requirements. FAO Irrigation and Drainage Paper No 24, 2nd ed., FAO Rome, Italy.

Gong L., Xu C., Chen D., Haldin S. and Chen Y.D., (2006). Sensitivity of the Penman-Monteith evapotranspiration to key climatic variables in the Changjiang (Yangtze River) basin, Journal of Hydrology, 329, 620-629.

Goyal R K 2004 Sensitivity of evapotranspiration to global warming: A case study of arid zone of Rajasthan (India); Agric. Water Manag. 69(1) 1–11.

McCuen, Richard H. "The role of sensitivity analysis in hydrologic modeling." *Journal of Hydrology* 18.1 (1973): 37-53.

McKenney, M.S., Rosenberg, N.J., 1993. Sensitivity of some potential evapotranspiration estimation methods to climate change. Agricultural and Forest Meteorology 64, 81–110.

Saxton K.E., (1975). Sensitivity analysis of the combination evapotranspiration equation, Agricultural Meteorology, 15, 343-353.

Singh, V.P., Xu, C.-Y., 1997. Sensitivity of mass transfer-based evaporation equations to errors in daily and monthly input data. Hydrological Processes 11, 1465–1473.