Results And Analyses

CHAPTER 9

RESULTS AND ANALYSIS

9.1 METEOROLOGICAL PARAMETERS

Principal methods for estimating ETo are based on climatic variables. For accurate estimates of ETo a long term weather record is required as source of data for such methods. Considering this aspect 10 to 30 years data are collected and analysed as weekly average values for five stations. Inspite of a few deviations in the distribution of all meteorological data in a span of year, it can be seen from the discussions made in para 6.3 that the parameters are uniformly following a pattern throughout year. Analysis made for climatic variables for each station and also for each variable stationwise shows that except one or two cases good correlation is maintained amongst them. Thus it can be said that the data collected can be used to develope a relationship with enough confidence. Therefore climatic data of five stations were considered to calculate ETo.

9.2 EFFECT OF LOCATIONS ON ETo

9.2.1. An attempt is made to know ETo variations among different stations for a particular method. For purpose of this study, potential evapotranspiration is taken as an index of water requirements. Weekly values given by four methods of FAO and average weekly ETo using Hargreaves and Jensen-Haise methods are used. To interprete the variation in ETo values amongst different stations data summarised in tables 7.1 to 7.7 and 7.13 is represented graphically.Fig. 9.1 shows ETo calculated by Penman method for all the stations. Accordingly figures 9.2 to 9.7 shows ETo calculated by Blaney-Criddle,Radiation,Panevaporation, Hargreaves,Jensen Haise and Thornthwaite methods for all the stations. From figures 9.1 to 9.7 drawn for each method following inferences are made.

9.2.2 ETo by Penman method

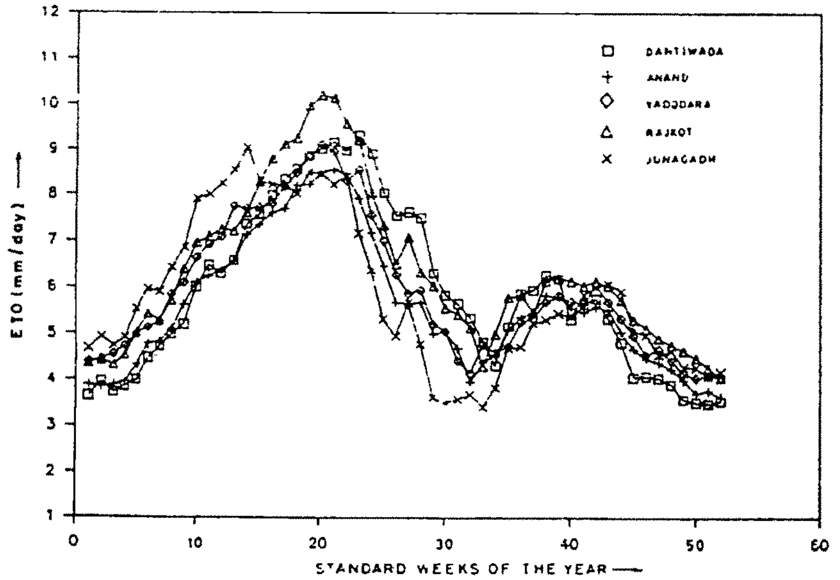


FIG: 9.1-ETO BY PENMAN METHOD

Figure 9.1 indicates that for different locations in

Gujarat the variation in ETo by Penman method is following uniform pattern. For Rabi season and late monsoon less deviations are observed. However from 10 to 33 week of the year results of all five stations are not in close proximity with each other. Penman equation includes Radiation and aerodynamic term . From the discussion for meteorological parameters, it reveals that for all locations under study, the results of temperature, sun shine hours and humidity are in close relation , whereas wind velocity and pan-evaporation varies with location. Thus ETo by combination equation also varies with locations due to its aerodynamic parameters.

9.2.3. ETo by Blaney-Criddle method

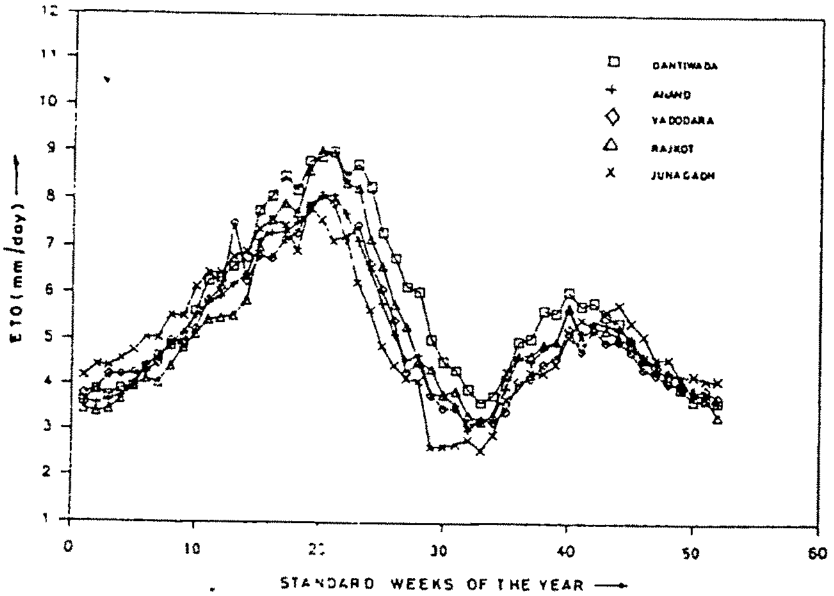


FIG:9.2-ETO BY BLANEY CRIDDLE METHOD

This method also shows (fig. 9.2) uniform pattern of variations throughout the year for different locations. Compared to Penman method less deviations are observed. Except 20th to 30th week ETo values of all five stations are within 1 mm range. Likewise Penman method this method also shows deviations during late summer and early monsoon.

9.2.4 ETo by Radiation method

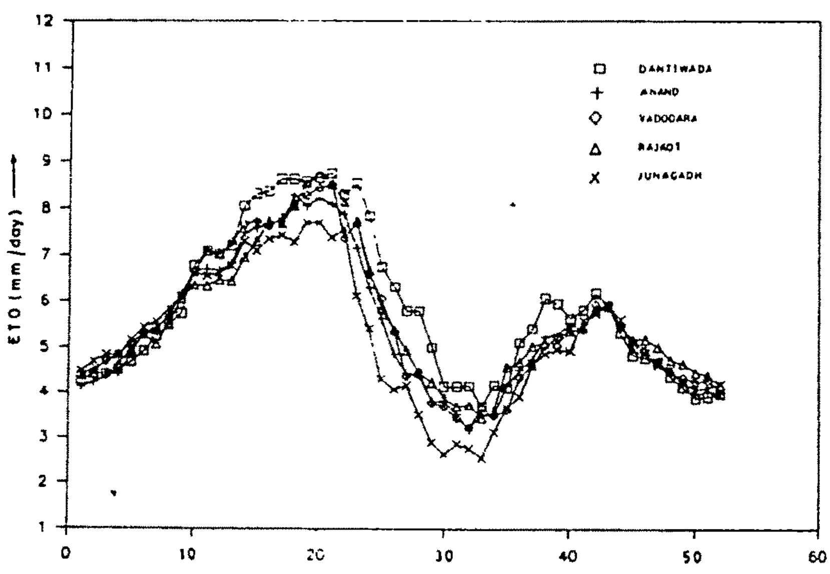


FIG-9.3-ETO BY RADIATION METHOD

Perusal made to the figure 9.3 indicates that this method shows all the results in very close proximity except for Dantiwada and Junagadh during middle part of the year. For Rabi season results of the different locations are within 0.5 mm range whereas for other part of year the variation for a particular week is in the range of 1 to 2 mm. The locations covered under study are in tropical region where temperature and sunshine are dominating climatic parameters. For the regions under consideration,data of temperature and sunshine hours shows close comparison and uniformity throughout year.Therefore ETo by Radiation method worked out for different locations shows good correlation with each other.

9.2.5 ETo by Panevaporation method

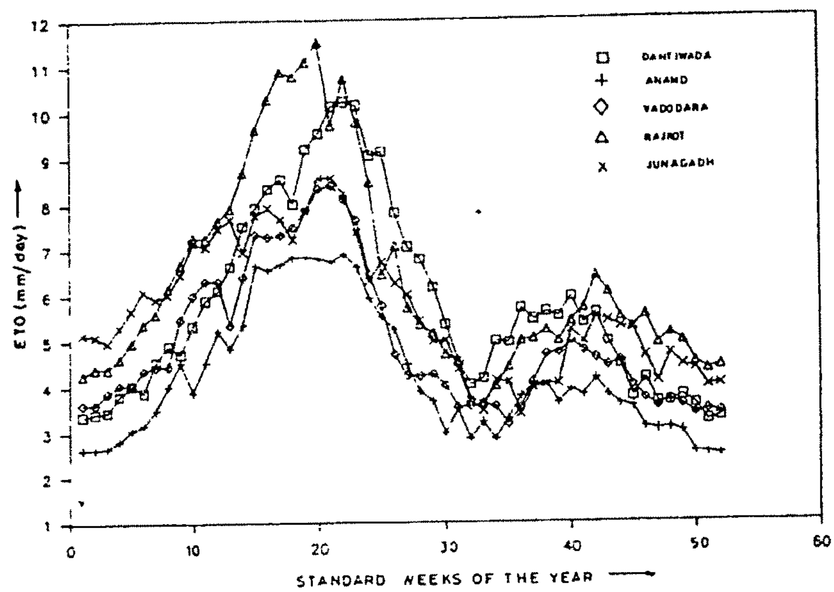


FIG:9.4 -ETO BY PAN-EVAPORATION METHOD

Wide range of variations seen in above figure 9.4 states that the location of Pan has laid an important role on the values of ETo. The results of five stations for a particular week are varing from 2 to 5 mm amongst each other.However their pattern of variation is same. In chapter 6 it is already discussed that the evaporation data for different locations shows more deviations compared to temperature and sunshine. This has affected the results of ETo by Panevaporation method.

9.2.6 ETo by Hargreaves method

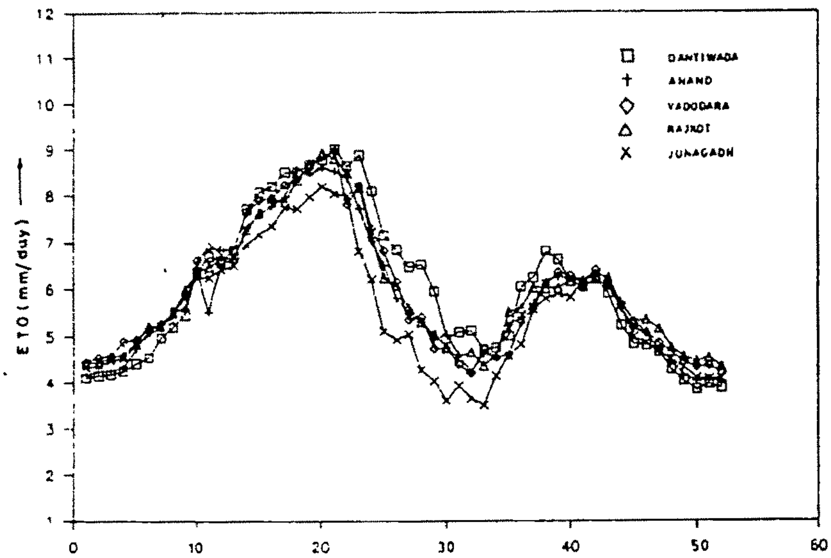


FIG: 9.5- ETO BY HARGREAVES METHOD

This method shows (fig 9.5) very close relation between the values of Rajkot, Anand and Vadodara. For Dantiwada and Junagadh stations, the results are in close proximity from January to March and October to December. For middle part of the year, variation between all locations for a specific week is in the range of 1 to 2 mm. Thus for all locations satisfactory correlation is seen for ETo by Hargreaves method.

9.2.7 ETo by Jensen-Haise method

Figure 9.6 shows that ETo by Jensen-Haise method also follows the pattern of Radiation and Hargreaves method. Only Dantiwada and Junagadh stations have 0.5 mm deviations for late summer and early monsoon compared to other stations. Other results are within 0.5 mm range.

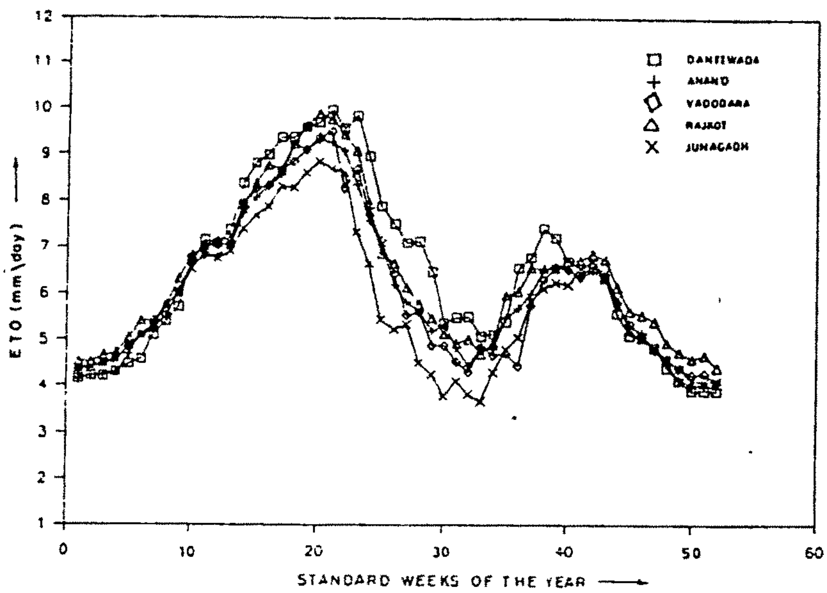


FIG: 9.6 - ETO BY JENSEN-HAISE METHOD

9.2.8 ETo by Thornthwaite method

Thorntwaite method shows (fig 9.7) lower ETo for Rabi season and higher values during mid summer.The deviations amongst the results of different locations are within 0.5 mm range except Junagadh station which shows lower values from 18th to 40th week.

9.2.9 It is evident from the above discussions and figures 9.1 to 9.7 that the pattern of variation of ETo from 1st to 52nd week is uniform for all the locations for all methods. From 1st week in January it rises upto 20th week in mid of May and then follows a receding pattern upto 33rd week in August.

A secondary peak is achieved around 40th week in early October following lower values upto end of December. Thus the rise and fall in the ETo values in a span of year for all methods follows an identical pattern.

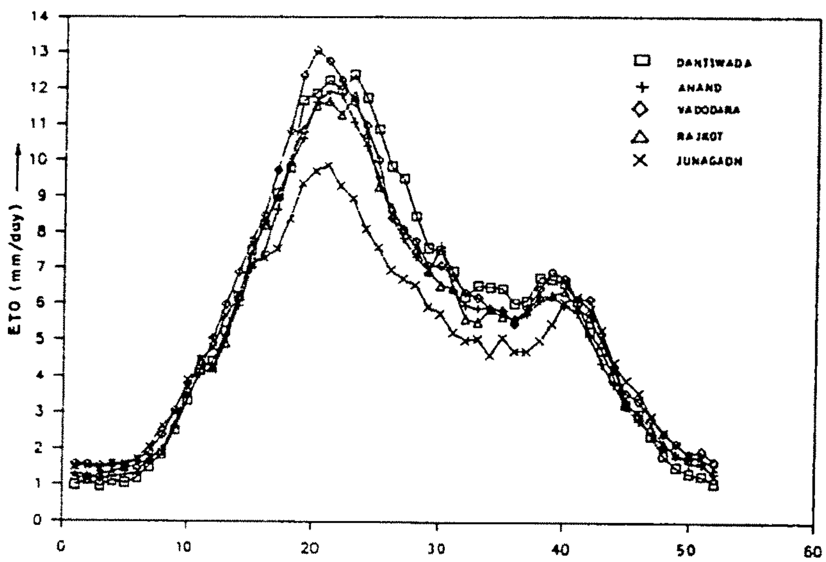


FIG:9.7 - ETO BY THORNTHWAITE METHOD

9.2.10 From the above analysis it can be said that effect of location on ETo values is less in case of temperature and the Radiation base methods.For combination method and the Panevaporation method the results of different locations are not in close proximity with each other.The reason of higher values for Dantiwada station is its location in North part of the state.As Junagadh station is located in foothills of Girnar it shows slightly lower values .

9.2.11 For Penman, Blaney-Criddle, Radiation, Hargreaves and Jensen-Haise methods even the difference between values amongst five stations for a particular week is negligible.Range of variation among five stations from January to mid of May and from August to December is less than 1.25 mm. For rest of the year such variation is 3 to 4 mm   Same observations can be made for Thornthwaite method except some values on lower side for Junagadh station. The difference between values of five stations for a particular week for Pan Evaporation method ranges from 3 to 5 mm.

9.3 COMPARISION OF ETo

9.3.1 With the background of analysis made, it can be derived that each method or a group of methods follows a specific and uniform distribution pattern throughout the year. Therefore a station based analysis is necessary to know the ETo variations amongst different methods for a particular station. An attempt is made in figures 9.8 to 9.14 to compare the results of various prediction methods for five stations and for regional average. These figures illustrate the stationwise estimated ETo values by seven/six pricipal prediction methods under study. A review of figures 9.8 to 9.14 indicates following facts.

9.3.2 Regional comparision- I

Figure 9.8 represents the comparision of ETo by different seven methods. The values of ETo are the average of all regions under study. A perusal made to the figure indicate that the distribution pattern of ETo by Thornthwaite method differs from other six methods. Values of ETo by Thornthwaite method are 3 mm lower for Rabi season and 3 mm higher for other part of year compared to other methods. With such larger variations it deviates from group of other six methods. Thornthwaite ETo is also varying from results of other Radiation based methods. Looking to such different pattern of Thornthwaite ETo, this method is not considered for further analysis.

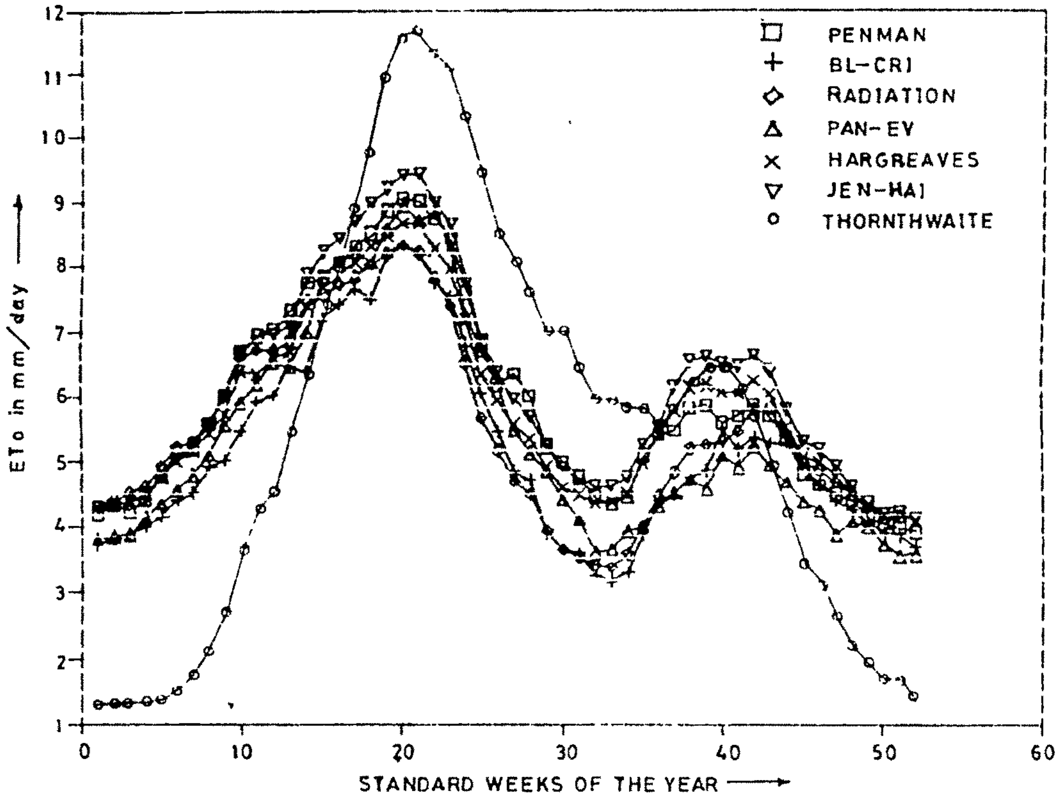


FIG:9·8 – ETo FOR GUJARAT BY SEVEN METHOD

9.3.3 Dantiwada station

As shown in fig 9.9 for Dantiwada station the variation of ETo by different methods follows uniform pattern for 52 weeks,having rise in values upto 20th week and lower values in 33rd week.The ETo calculated by different methods for a specific week shows 1 to 1.5 mm deviations. Thus all methods show uniformity. For Rabi season values of Panevaporation ETo are on lower side.During mid summer and late September Jensen-Haise ETo shows highest values.

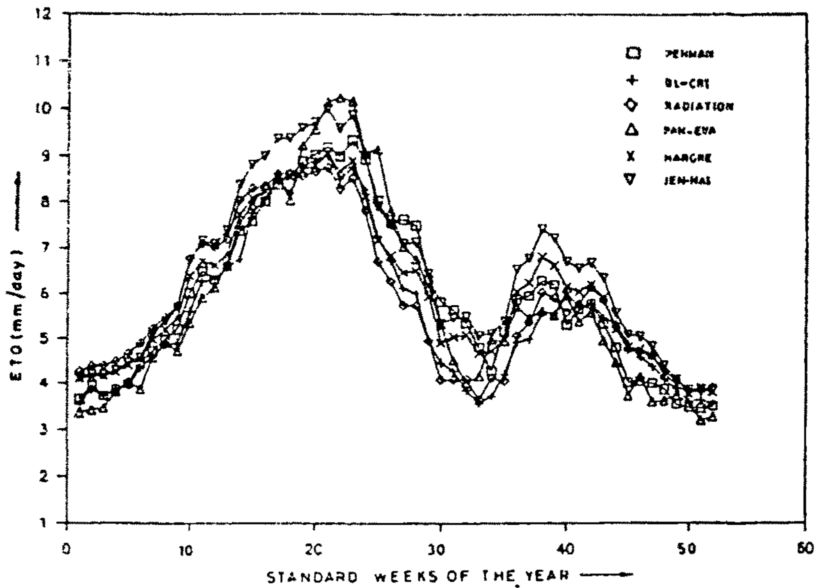


FIG:9.9 - ETO FOR DANTIWADA BY SIX METHODS

9.3.4 Anand station

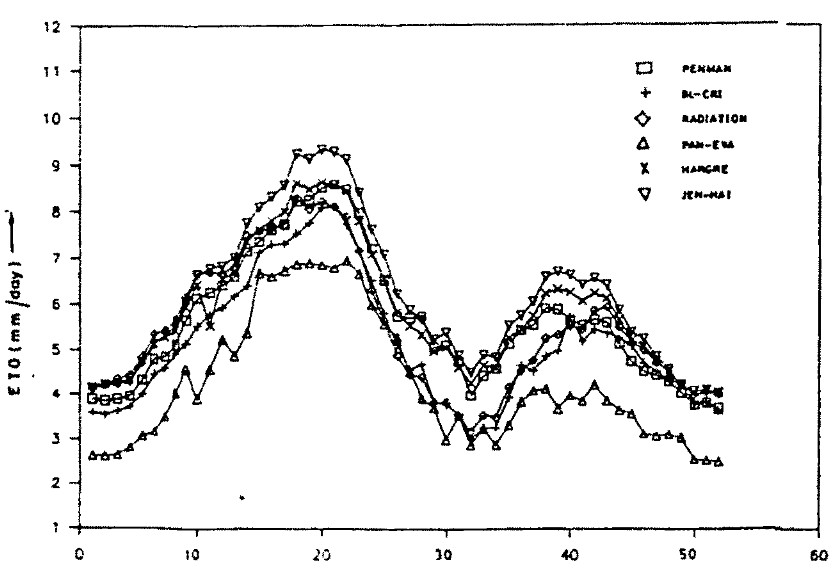


FIG:9.10 - ETO FOR ANAND BY SIX METHODS

For Anand region variation between different methods is more compared to that of Dantiwada(fig 9.10). However like Dantiwada the pattern of variation throughout year is uniform with rise in ETo values at 20th and fall in 33rd week.The ETo calculated by different methods for a specific week shows 2 to 4 mm deviations.Excluding Panevaporation method this variation is within 1 to 1.5 mm range.Panevaporation ETo is on lower side for the entire year,whereas Jensen-Haise ETo shows higher values for summer and monsoon period.

9.3.5 Vadodara station

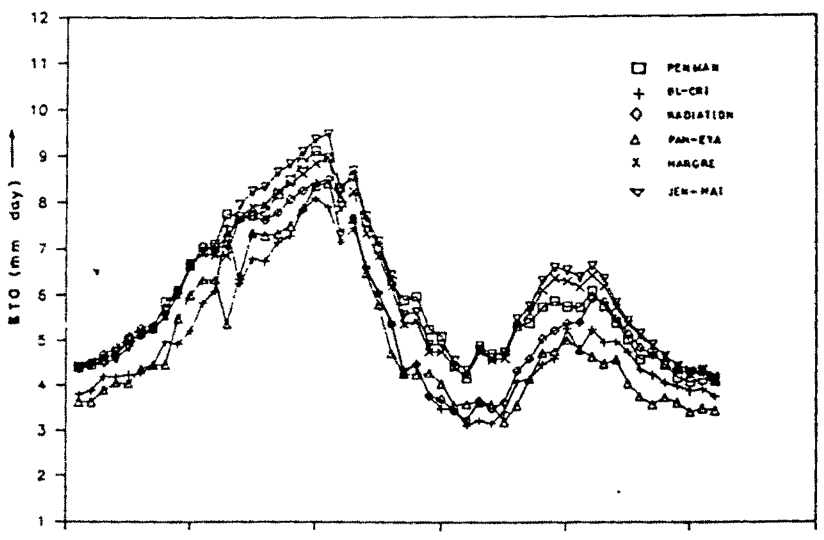


FIG:9.11-ETO FOR VADODARA BY SIX METHODS

Except a few deviations Vadodara station shows(fig 9.11) better and identical pattern than Anand. The variation amongst different methods are within 1.5 mm range.For all methods rise and fall in ETo values is uniform.For this station also Panevaporation ETo gives lower values for Rabi season whereas Jensen-Haise ETo shows higher values during mid summer and late September.

9.3.6 Rajkot station

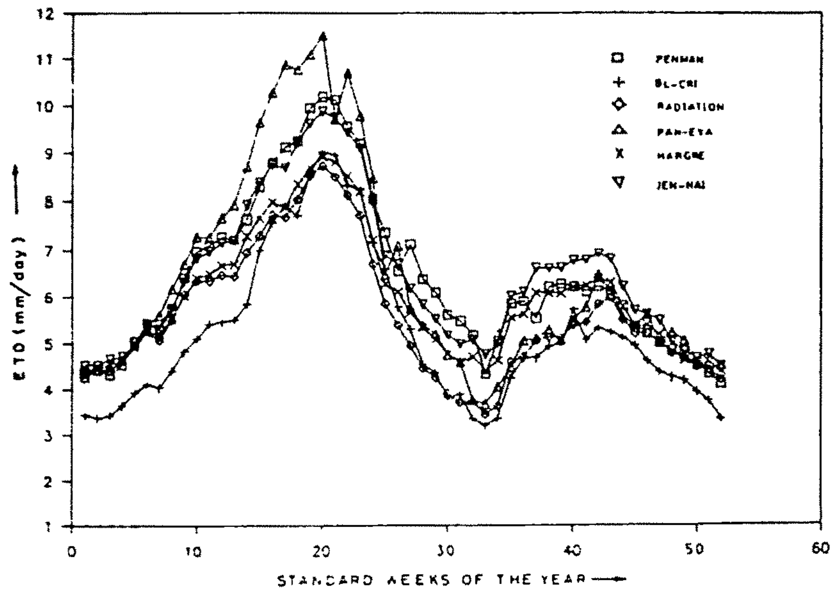


FIG:9.12 - ETO FOR RAJKOT BY SIX METHODS

Figure 9.12 for Rajkot station indicates higher values in 20th and 40th week and lower values in 1st and 33rd week. However the pattern of variation is uniform for all the methods. The difference in values of ETo between different methods for a particular week is ranging from 1.5 to 3 mm. ETo by Blaney-Criddle method is on lower side for the entire year except 20th to 30th week. For 20th to 30th week ETo by Radiation method is on lower side. In mid of May ETo by Panevaporation method gives higher values and in early October Jensen-Haise ETo gives higher values.

9.3.7 Junagadh station

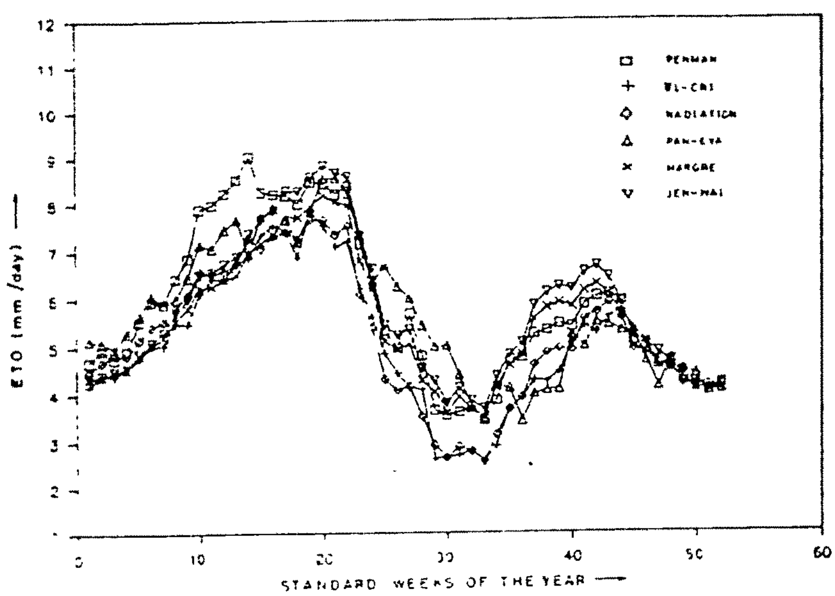


FIG 9.13 - ETO FOR JUNAGADH BY SIX METHODS

Variation of ETo by different methods for Junagadh station shows (fig 9.13) different pattern than other stations. The peak values in mid summer and low values in 33rd week are on lower side compared to other stations.All methods follow uniform variations in rise and fall throughout year.Rabi season shows values of different methods in a close proximity. The variation amongst ETo for a particular week ranges from 0.25 to 1.5 mm.

9.3.8 Regional comparison-II

Figure 9.14 represents the comparison of ETo by different six methods.The values of ETo are the average of all regions (stations) under consideration. Figure indicates that an uniform variation is observed amongst all methods. For 1st to 33rd week and for last 8 weeks the results are in good corelation.

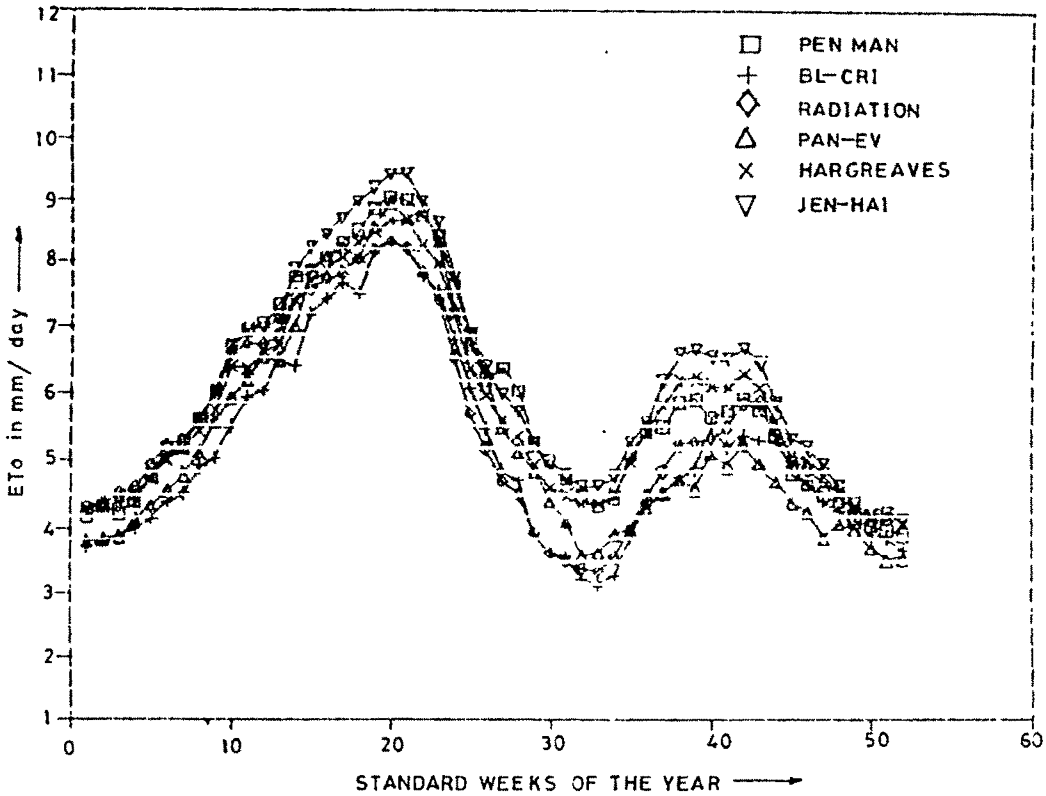


FIG:9·14 - ETo FOR GUJARAT BY SIX METHOD

For all the stations ETo requirement increases from 3.75 to 4.25 mm in January upto about 8 to 10 mm in mid of May. Onset of monsoon brings the requirements of ETo down upto 3 to 5 mm following an increase in ETo at the end of kharif season. During initial period of rabi season ETo value decreases.For all methods range of the ETo variation for a particular week of the year is from 1 to 2 mm

9.4 LINEAR RELATION BETWEEN BASIC CLIMATIC PARAMETERS

9.4.1 The calculation of ET estimate from weather records is appealing because the approach is relatively simple compared to onsite ET measurements. Various researcher have developed methods under different conditions. An attempt is made under this study to develop a simple equation which is best suited for the regions under considerations. ETo values used are based on average of six different methods and therefore such values can be used without much loss of accuracy.As discussed hereinabove the ETo values by six different prediction methods have less variation amongst them. Also all methods are giving good correlation for different locations except a few deviations. The pattern of variation of all meteorological parameters also follows a specific path along the year. Thus equation developed in following form will give reliable values for the region under study.

$$ETo = C + C_1 * T + C_2 * n + C_3 * RH + C_4 * U$$

In the following paras whenever the reference to this equation is made will be known as Met-Para equation. This is a very simple, direct and explicite equation which does not require any charts and observed meteorological parameters can directly be used. As relative humidity is inversely proportional to temperature, sunshine and wind velocity, its constant is having nagative sign in the equation.

9.4.2 The climatic variations in Gujarat are such that the curves of ETo shows two peaks. Looking to such distribution a best fit curve based on least square method is not possible for year as a whole with good coefficient of correlation. To take care of such specific nature of curve analysis is made in two parts. Thus two equations are developed. Figure 9.15(a) shows the correlation between ETo estimated by Met-Para equation with ETo estimted by different prediction methods under study. Similarly figure 9.15(b) shows the correlation between ETo estimated by Met-Para equation with ETo calculated for different stations under consideration. The comparision of ETo calculated by Met-Para equation and average ETo of all methods is illustrated in figure 9.15(c). Thus this linear relationships with four basic climatic parameters exhibit good correlations.

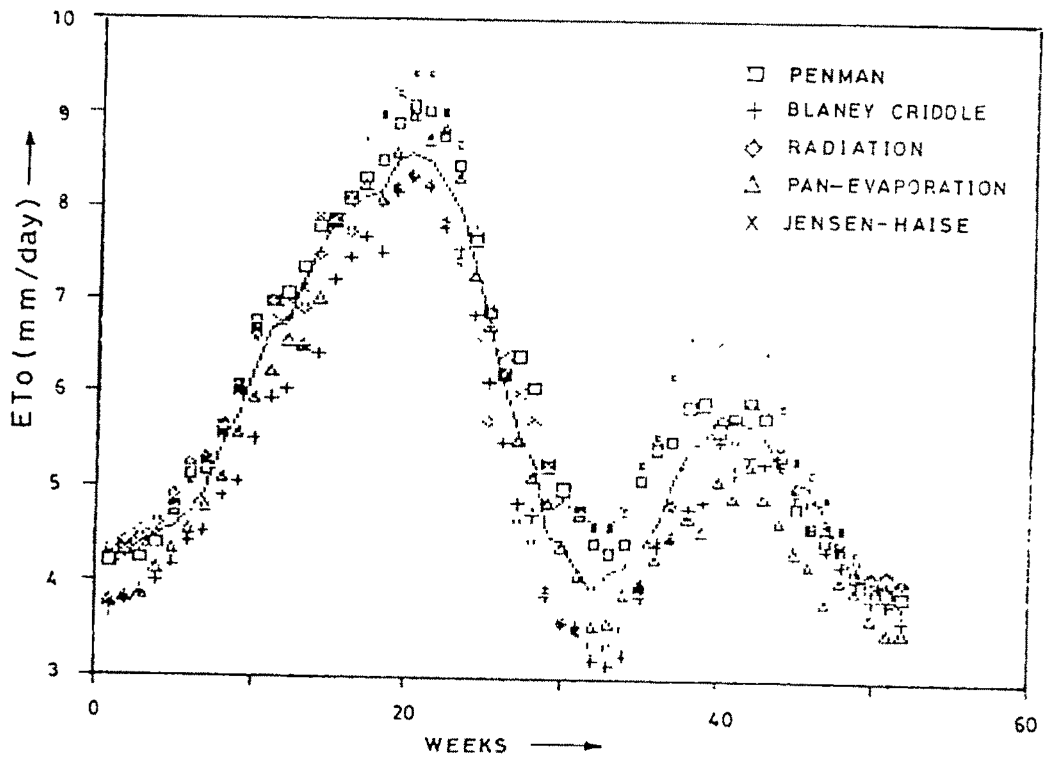


FIG:9·15(a)-COMPARISION OF ETo BY MET-PARA EQUATION & ETo BY METHODS

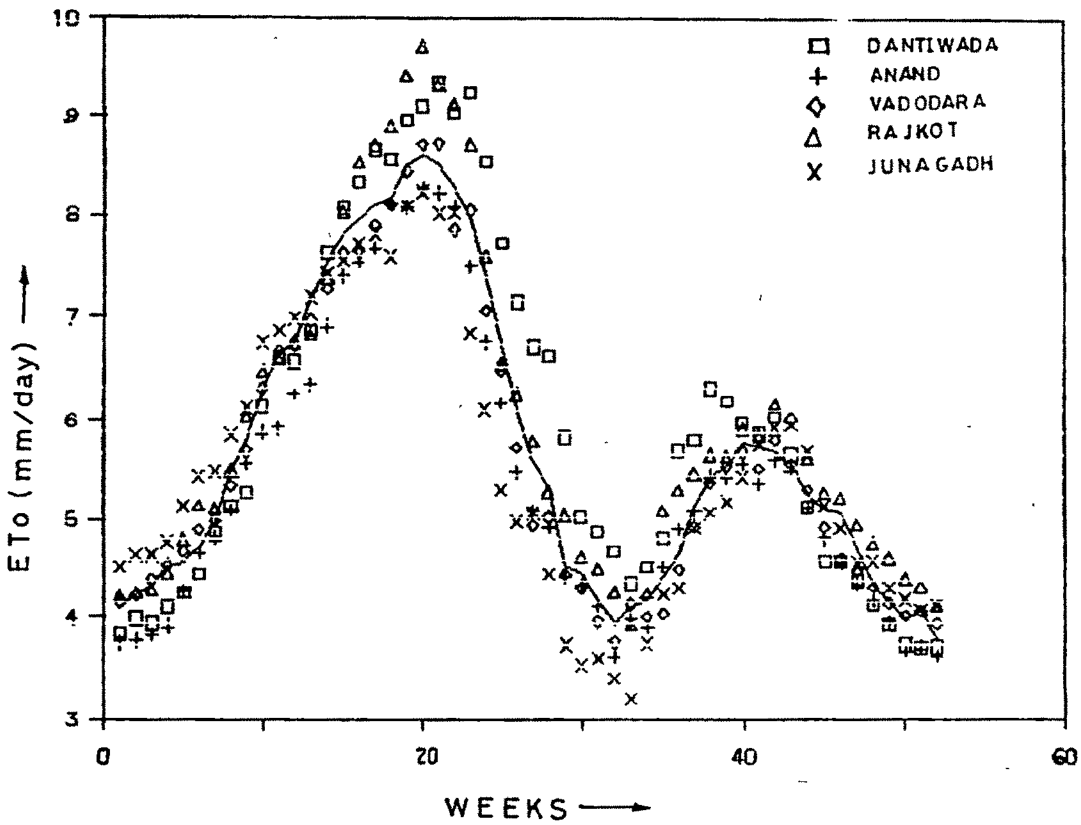


FIG:9-15(b)-COMPARISION OF ETo BY MET-PARA EQUATION & ETo BY STATIONS

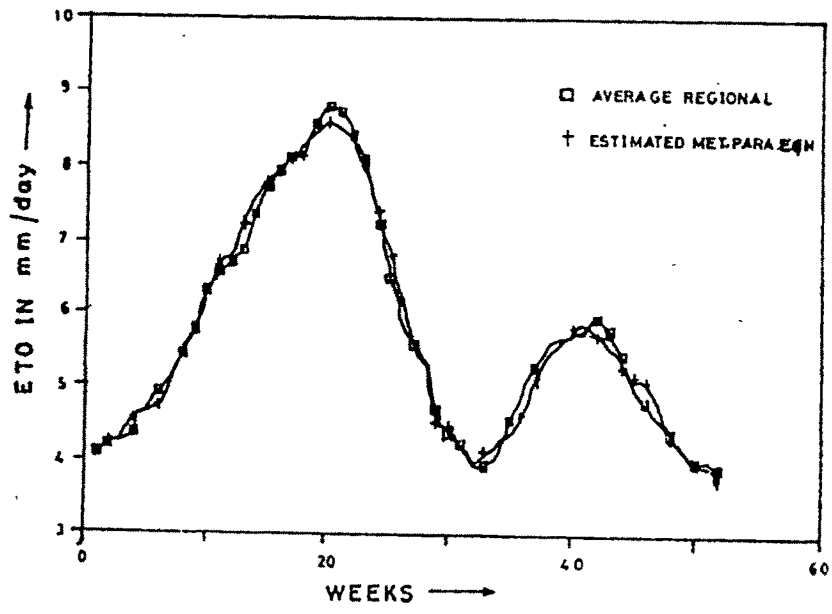


FIG:9-15(C)-COMPARISION OF ETO

9.4.3 For estimating ETo values for different stations, the calculated values using these equations are required to be reduced or increased by 5 % to 9 % by applying necessary coefficients mentioned in para 8.2.4. The regional relationship developed is apllicable for the whole region under study. However to derive accurate results, correction coefficients are evaluated which takes care of local effects. Without using such coefficients ETo can be estimated with an accuracy of -5 % to +9 % .

9.5 TEMPERATURE AND RADIATION AS AN INDEX OF ETo

9.5.1 Numerous approaches can be used to estimate ETo. Many empirical methods for estimation of ETo have been used in past, most of them based on temperature and radiation. The principle amongst them are Blaney-Criddle (1945,1950,1962), Thornthwaite (1948), Lowry-Johnson (1942), Makkink (1957), Turc (1961), Grassi, Jensen-Haise (1963,1974) and Hargreaves (1956,1975,1985). Each of above method have its own advantages and disadvantages for use in practical applications. Many researchers like Shih, Hargreaves and Samani found that a method based on air temperature and solar radiation could be used for estimating ET for arid and semiarid regions because this method gave an irrigation requirement prediction sufficiently close to that estimated by the combination method. It is also claimed that the methods based on these two parameters are superior. Moreover advantage of these methods are that they require only the more commonly measured data and simple calculations. Also the absence of availability/unreliability of humidity data is often cited as a reason for not using combination equations in practical use.

9.5.2 The analysis made in chapter 8 reaches to a conclusion that when any single parameter is used to estimate ETo, except pan evaporation data, good correlation is not found. The variations of temperature and ETo is same for whole year except during monsoon when the drop in ETo values is more compared to temperature. Looking to the variation in sunshine, it can be seen that there is sharp fall in the values during monsoon which may be the reason for lower values of ETo during monsoon. This leads to develop a temperature and sunshine based equation. The developed (T-n) equation is in following form.

$$ETo = C_0 + C_1 T^2 n$$

In the following paras whenever the refernece to this equation is made will be known as T-n equation. As the predicted values with this equation shows higher nature of curve during rabi season, a correction factor of 0.95 is suggested. These derived values of ETo are further required to be corrected for each station to take care of the local environmental conditions.

9.5.3 A good aggrement is found between the estimated ETo values using T-n equation compared with ETo estimated by other methods as shown in figure 9.16(a) Similarly figure 9.16(b) indicates that the ETo derived from T-n equation matches with the ETo of all stations under study. Figure 9.16(c) shows the averge calculated ETo and ETo estimated by T-n equation. This T-n equation is verified with actual field observed evapotrnspiration values and found in good aggrement.

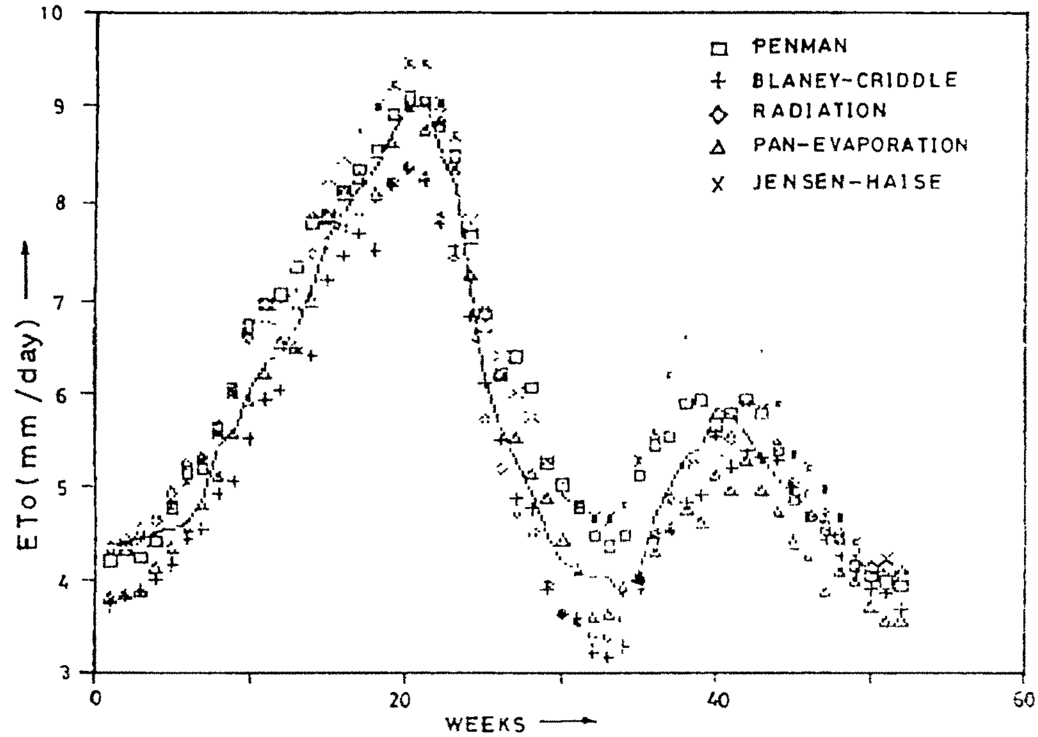


FIG: 9.16 (a)- COMPARISION OF ETo BY T-n EQUATION & ETo BY METHODS

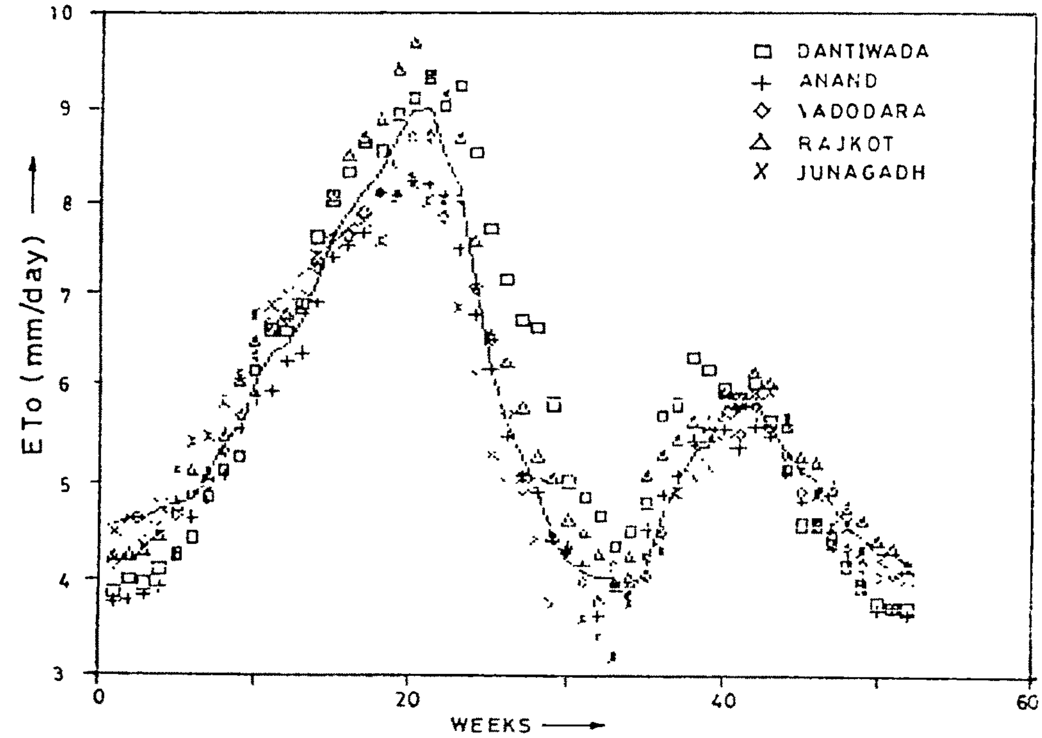


FIG:9.16(b)-COMPARISION OF ETo BY T-n EQUATION & ETo BY STATIONS

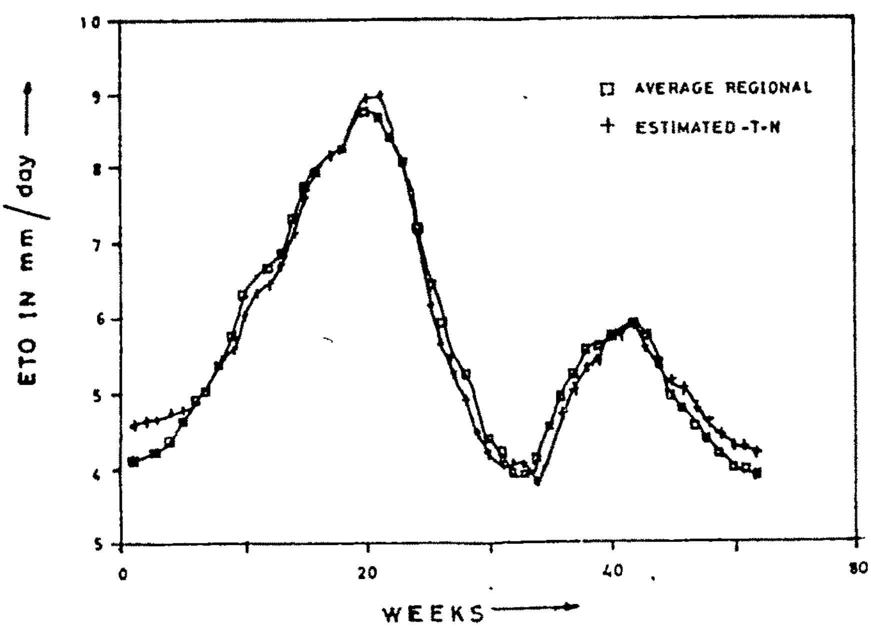


FIG:9.16(C)-COMPARISION OF ETO

9.6 PAN EVAPORATION AS AN INDEX OF ETo

9.6.1 The evaporation pan provides a measurement of evaporation from an open water surface integrating the effects of radiation, wind, temperature and humidity. Hence several researchers have attempted to correlate pan evaporation with evapotranspiration. Similarly pan evporation based linear regressin model is developed. The ratio between ETo and Pan evaporation (Epan) has been an useful index in investigations on water balance for determining irrigation schedules on an operational basis . The ratio of ETo and Epan from a class - A pan increases from about 0.8 for short crops to 1 for tall crops. In the case under study, with such direct ratio between these two parameters good corelation is not arrived.Considering this aspect relationship between these two is attempted in different form. The developed regional equation is in the following form with correction factors for local effect for other stations.

$$ETo = Co + C1\ Epan$$

In the following paras whenever the reference to this equation is made will be known as Pan-Ev equation.

9.6.2 As shown in figure 9.17(a) calculated values of ETo using Pan-Ev equation are having good correction with the estimated ETo by all methods. Figure 9.17(b) shows the comparison of ETo estimated by all stations with ETo estimated by Pan-Ev equation. Average regional estimated value of ETo for five stations are compared with ETo by Pan-Ev equation in figure 9.17(c) and found in good agreement.

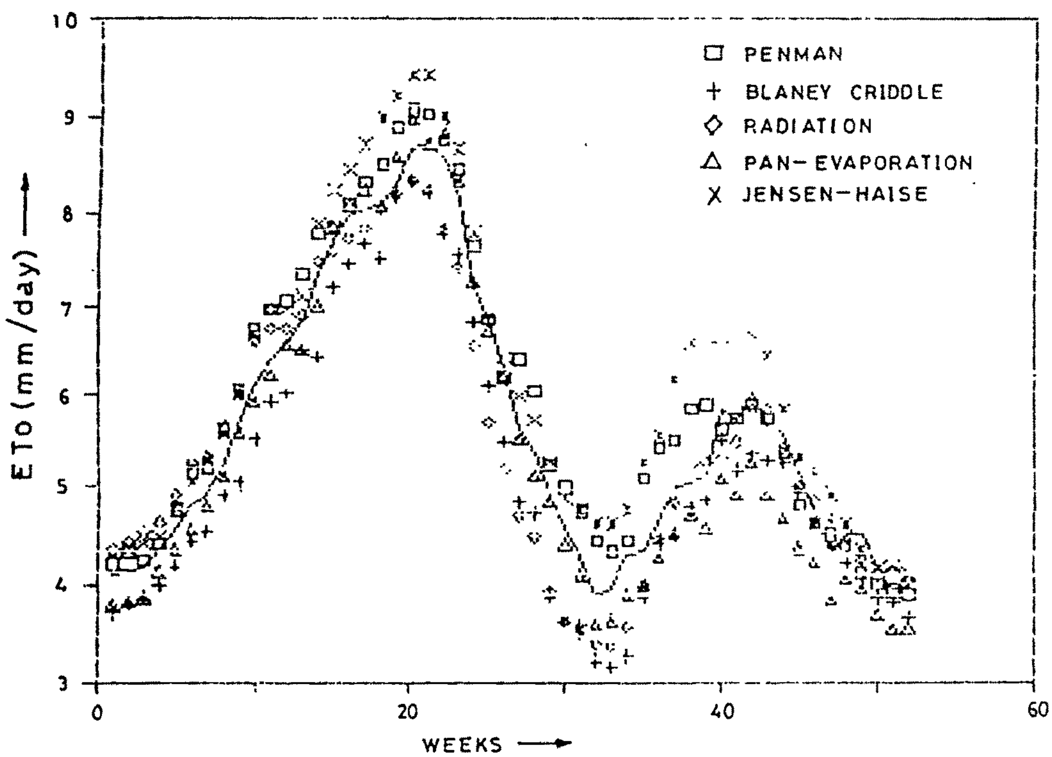


FIG:9·17(a)-COMPARISION OF ETo BY PAN-EV EQUATION & ETo BY METHODS

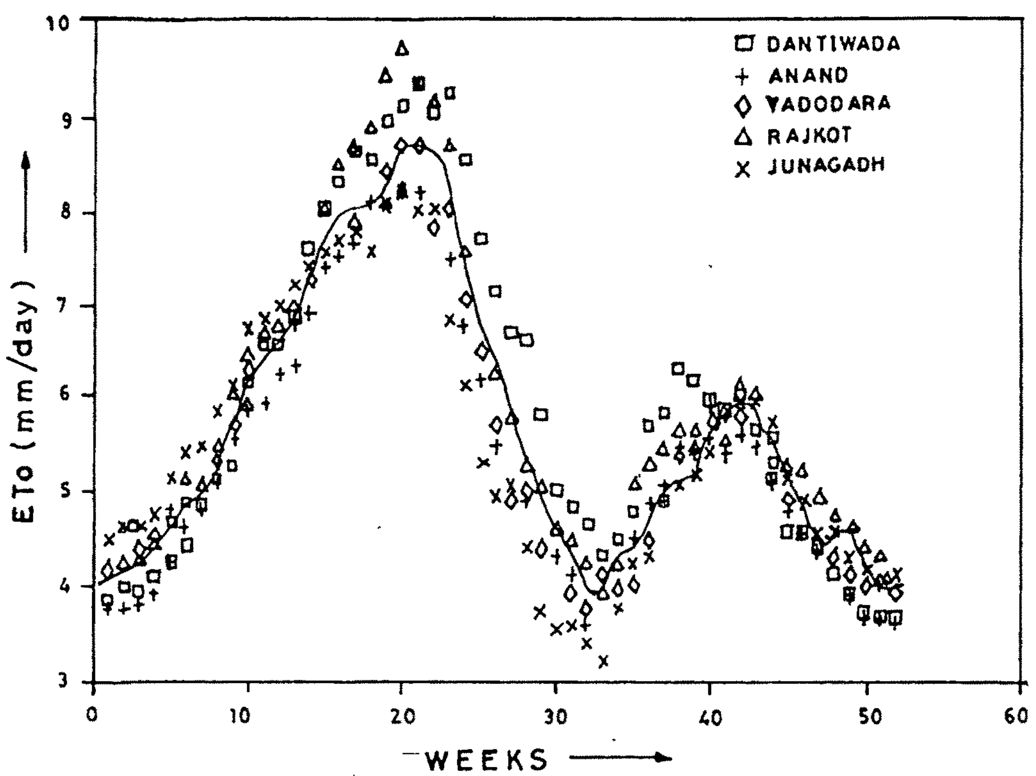


FIG: 9·17(b)-COMPARISION OF ETo BY PAN-EV EQUATION & ETo BY STATIONS

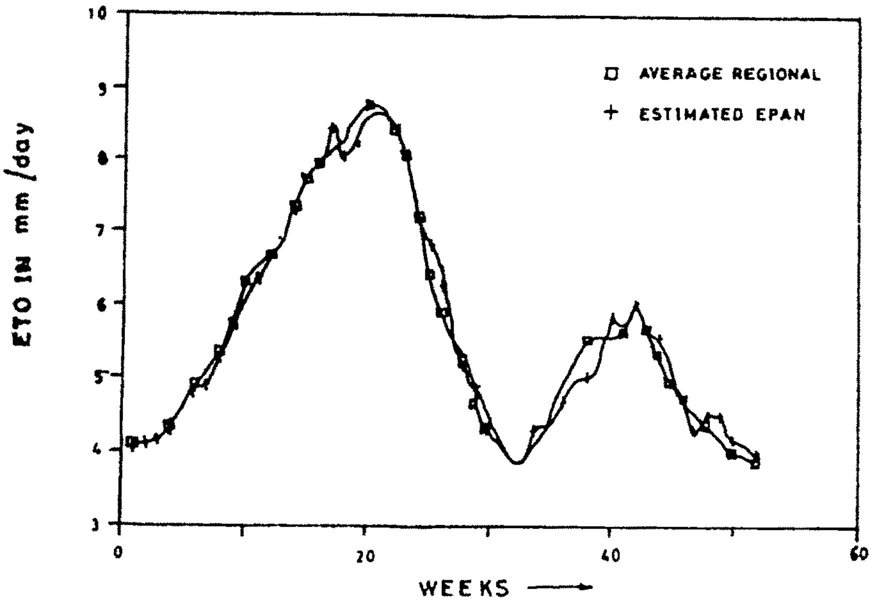


FIG:9·17(C) COMPARISION OF ETO

9.6.3 The method of estimating evapotranspiration using this approach can be used successfully if only the information of evaporation of the area is known.The advantage of pans is that they provide a cheap and simple method of obtaining what would otherwise require elaborate instrumentation.

9.7 WEEK AS AN INDEX OF ETo

9.7.1 The average value of basic climatic variable, based on long record of weather data, can be used for reliable estimation of ETo. Weather records of longer period is considered in this study for estimation of ETo. An average ETo value obtained by six well known methods shows that the variation of ETo is a function of time. Considering this aspect a multiple regression model for estimation of ETo is used to develope five degree polynomial equation as a function of time. Various additive and multiplying constants are derived for local effects of different stations as shown in table 8.1 Figure 9.18 exhibit a comparision of an average ETo values by various methods and ETo estimated by week based equation. This equation requires single variable i.e. week , starting from beginning of calender year.

9.7.2 This simple equation which gives good results is derived from record of 10 to 30 years meteorological data.After each 10 years period it is necessary to check the changing trend in the climatology.As this equation is based on weeks and do not include any climatic variable, the applicability of this type of equation is required to be checked from time to time. The calibration of this equation is to be made by adding latest 10 years data and deleting the oldest 10 years data.

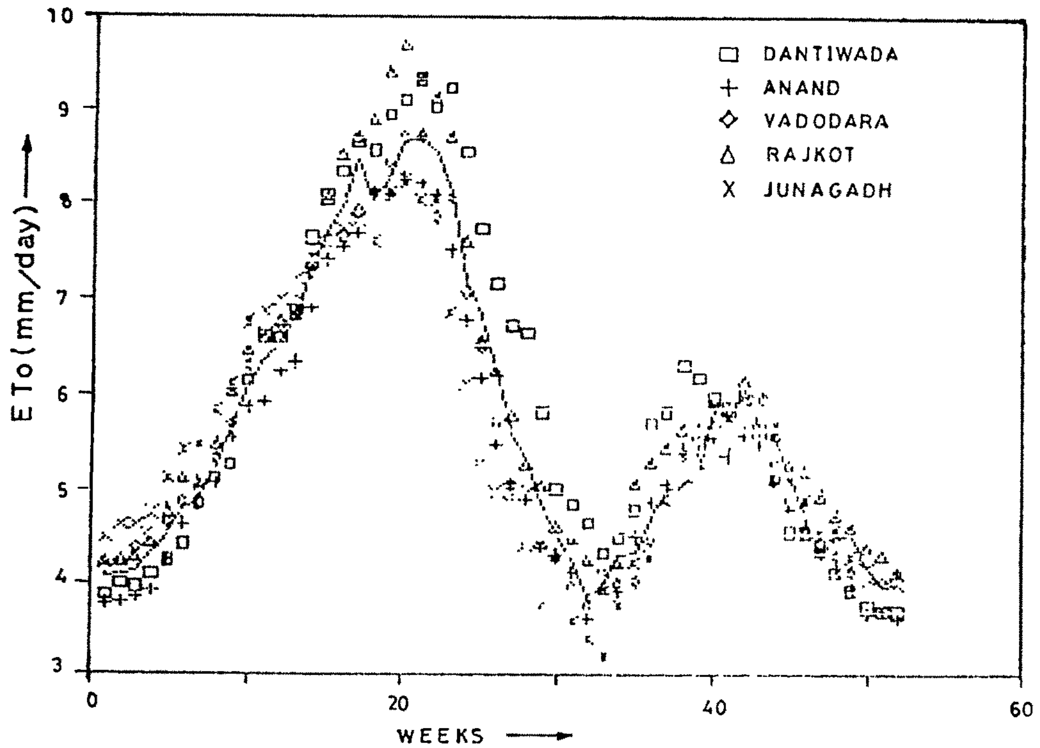


FIG:9.18-COMPARISION OF ETo BY WEEK BASE EQUATION & ETo BY STATIONS

9.8 FIELD CORRELATION

9.8.1 Lysimetric value for Cotton, kharif Groundnut, Tobacco, Maize, Bajara and Mug are collected from three premier agricultural institutes. These crops are the major crops of the region under study. The observed values are compared with calculated values by T-n method. The comparision of observed and estimated evapotranspiration values for three stations is given in figure 9.19, 9.20 and 9.21. It reveals that for each crop the estimated ETcrop curve falls in the area covered by actual ETcrop values. Thus the ETo estimated by developed T-n equation sim ulate the field conditions. To know the total crop water requirement at end of a particular week, starting from the date of sowing, cummulative curves are plotted as shown in figures 8.2 to 8.11.

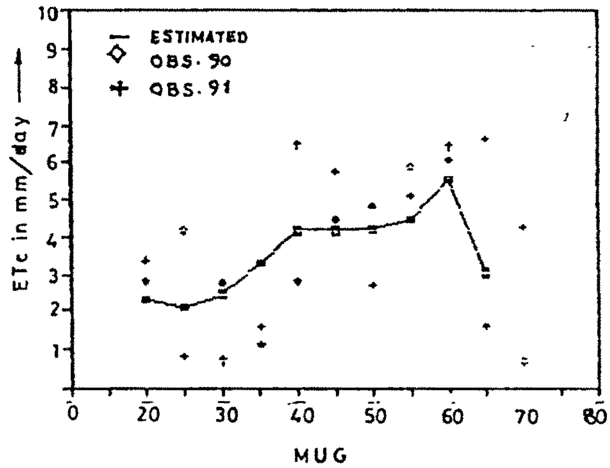
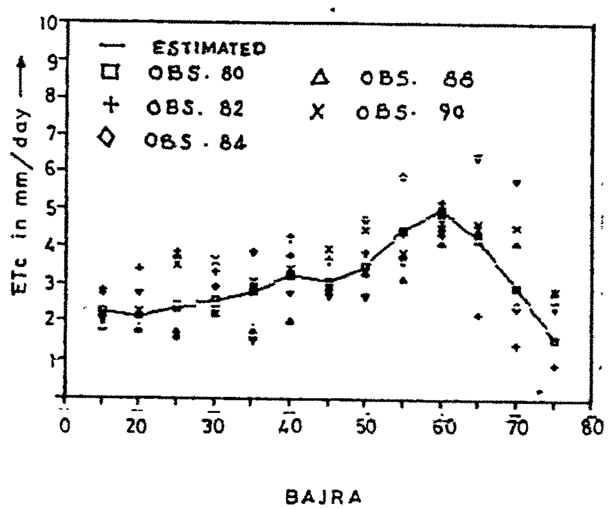


FIG: 9.19 - COMPARISION OF OBSEVED AND ESTIMATED ETo AT DANTIWADA



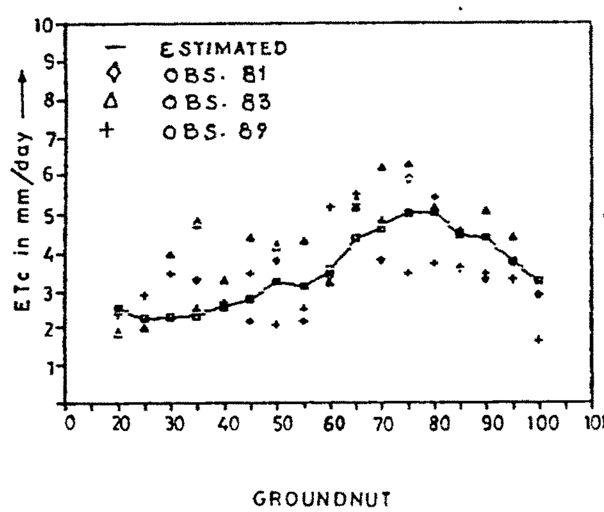


FIG: 9.20 - COMPARISION OF OBSERVED AND ESTIMATED ETo AT RAJKOT

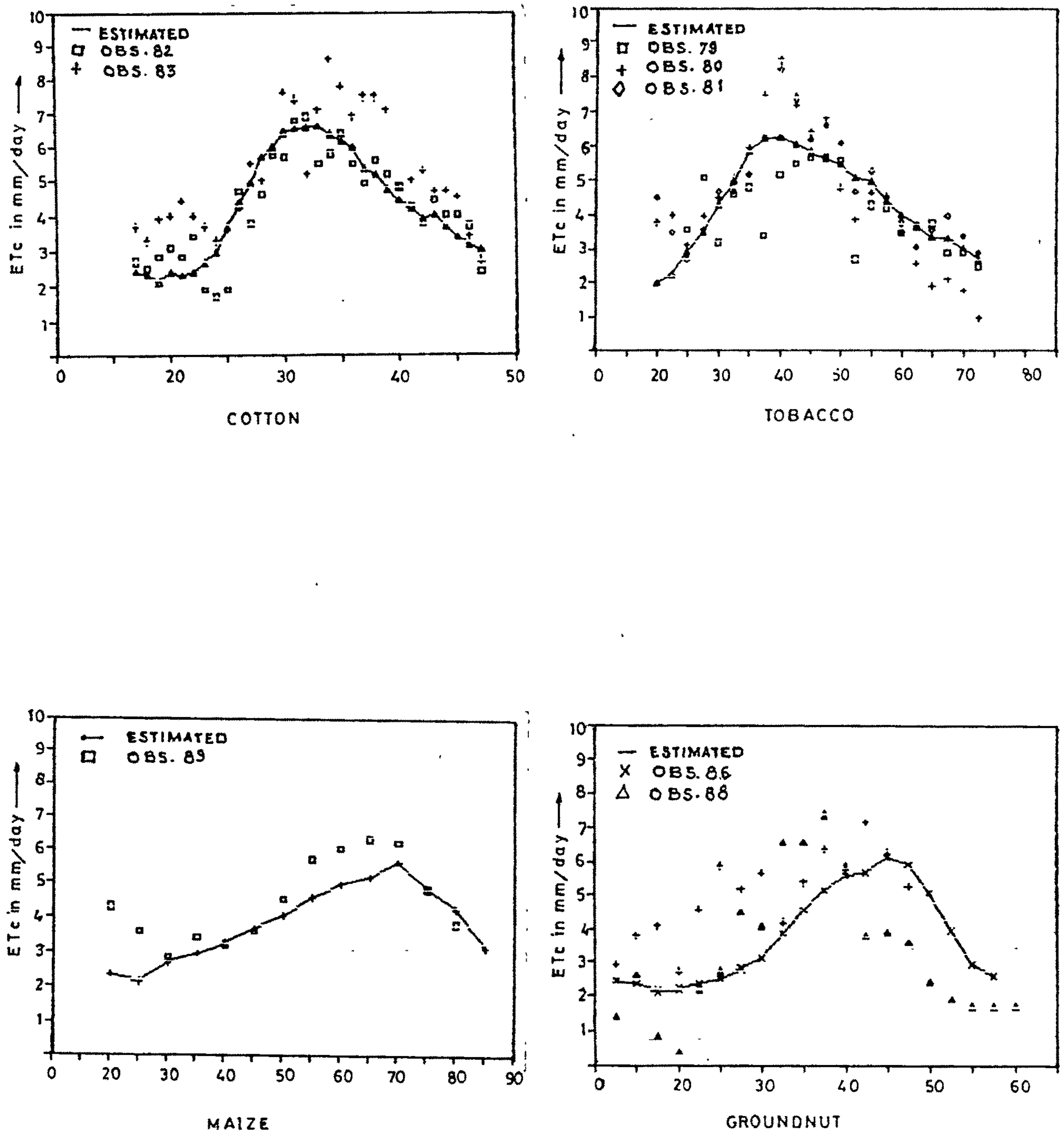


FIG: 9·21 – COMPARISION OF OBSERVED AND ESTIMATED ETo AT ANAND

The perusal of figure 9.19 to 9.21 would indicate that

(1) Out of seven different crops grown in ten different growing seasons, majority of crops matches with the estimated crop water requirements.

(2) For Mug at Danatiwada, Maize and Ground Nut at Anand fortnightly water applied to the crops in field shows more deviations resulting in scattered points in the graphs. However total requirement at the end of season matches with the observed values.

(3) For Bajara at Rajkot a good data of about five years is available. The T-n equation shows the close conformity with the observed evapotranspiration (ETc).

(4) Similarly for Ground Nut at Rajkot also close comparision is observed amongst the observed and estimated values.

(5) For Cotton and Tobacco at Anand the estimated values of ETc by T-n equation shows close comparision with the observed values except a few deviations.

9.9 LIMITATIONS OF THE DEVELOPED EQUATIONS

(i) The relationships developed for ETo on climatic data base are recommended for the use without much loss of accuracy. However these developed relationships are regional and before using it for the other regions its calibration is necessary.For each sub region a correction factor is suggested.

(ii)These equations will give good results for the average weekly Humidity ranges as under :-

Maximum Relative Humidity - 50 % to 90 %

Minimum Relative Humidity - 18 % to 72 %

The limits are given based on 10 to 30 years data of five stations under study.However for any specific condition beyond these limits,calibration of formulae is required.

(iii) Similarly the equations are applicable for wind velocity ranging from 2.5 to 20 km/hr.

(iv) The week based equation is developed considering week as the only variable. The equation as a function of time is developed using 10 to 30 years data. It is necessary to calibrate it by adding last 10 years data and deleting the oldest 10 years data,for each decade.

(v) The Epan equation based on single observations of pan evaporation is easy to solve and gives accurate results.It can be applied under following conditions.

(i)Humidity & wind velocity ranges as mentioned in (ii)

(ii) Temperature range : 9 to 42 degree celsius

(iii) Sunshine hours range : 2 to 12 hr.

(vi) The T-n equation is recommended as regional relationship for five regions under consideration.It is also checked with field data.However it can not be applied for the temprature below 9 degree celsius without calibration.

(vii) The T-n equation is checked with lysimeter data and good corelation is seen.However the lysimeter data available is for the major grown crops in the area under consideration. For other crops its calibration is necessary.

(viii) The equations developed covers the altitude range of 25 m. to 300 m. from mean sea level.For altitudes 0 to 25 m. and higher than 300 m. a calibration is necessary.