Regional Relationships

CHAPTER 8

REGIONAL RELATIONSHIP

Principal climatological variables are analysed for developing regional equations. Relationships for ETo based on one or more climatic parameters are developed. Correction factors for each sub region are also developed. A novel concept of week as a variable parameter is used in developing a simplified equation. Verification of these equations with actual evapotranspiration is also discussed.

8.1 GENERAL METHODOLOGY

Evapotranspiration of crop mainly depends upon climatological factors and therefore an attempt is made to develop equations based on such climatological factors. An averege of long record of such climatic data is used to develop empirical equations. The relationship is based on average ETo derivd from the results of various prediction

methods.

8.2 RELATIONSHIP BASED ON METEOROLOGICAL PARAMETERS

8.2.1 Data of various parameters ranging from 10 to 30 years are collected and analysed as discussed in chapter 5 and 6 and these data are used for developing equations. Table 6.1 to 6.5 shows the abstract of all data in form of weekly average values for all years. Table 6.6 shows the weekly average values of all meteorological parameters for regions under consideration.

8.2.2 The potential evapotranspiration for all the stations and by all seven methods are already given in tables 7.1 to 7.13. The prediction methods used for ETo estimation are either based on single or two climatological parameters or on combination equation. Thus the ETo calculated by six methods includes various approach towards the estimation procedure. The results also shows that the estimated ETo by six methods have less deviations with each other. Therefore the average values of ETo estimated by six methods are considered a reliable base for the comparision of climatological data with evapotranspiration.

8.2.3 Table 7.13 is used to draw curves for each station and figures 8.1 shows the ETo value in mm/day for 52 weeks for Dantiwada, Anand, Vadodara, Rajkot and Junagadh stations. The figure 8.1 (f) shows average ETo curve for the whole region. The perusal of figure 8.1 indicates the necessity of devloping equations in two parts, upto 33rd week and beyond that.

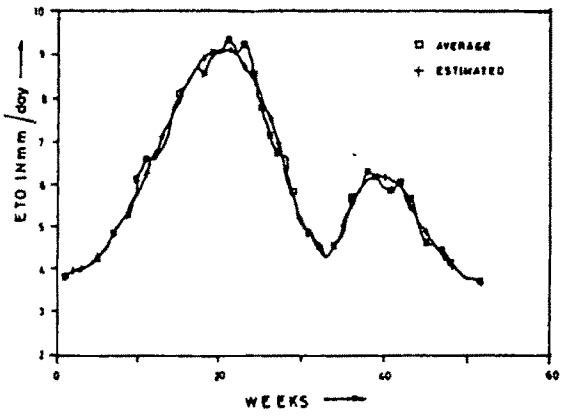
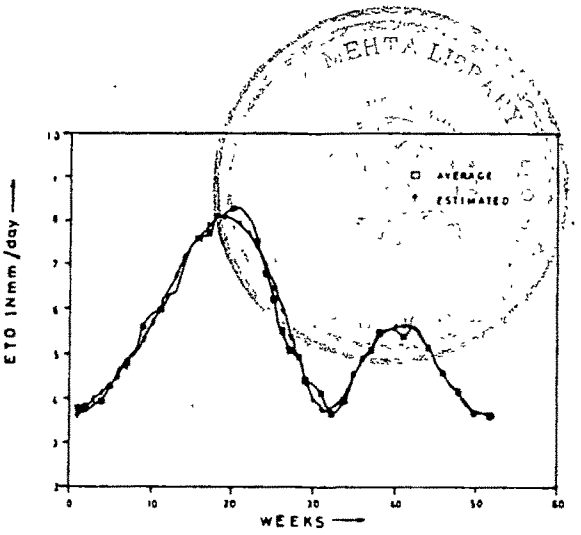
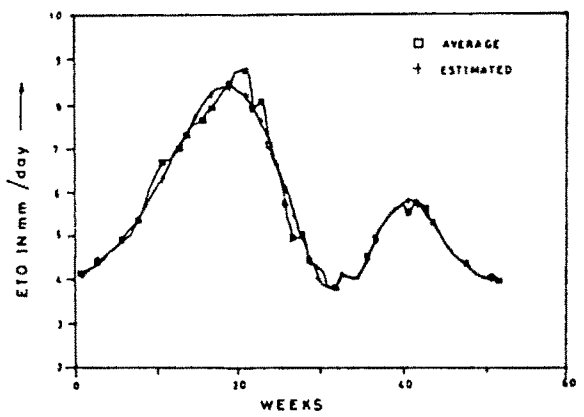


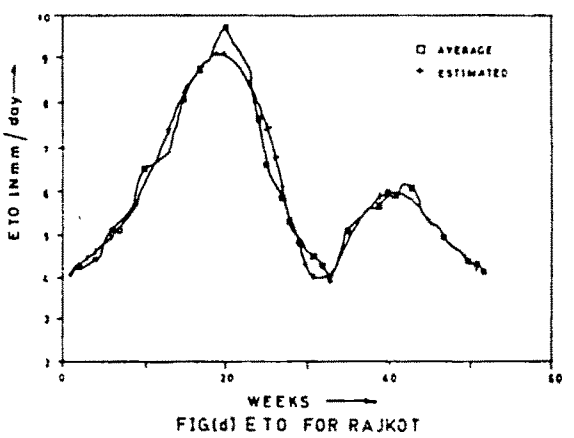
FIG.(a) ETO FOR DANTIWADA



FIG(b) ETO FOR ANAND



FIG(c) ETO FOR VADODARA



FIG(d) ETO FOR RAJKOT

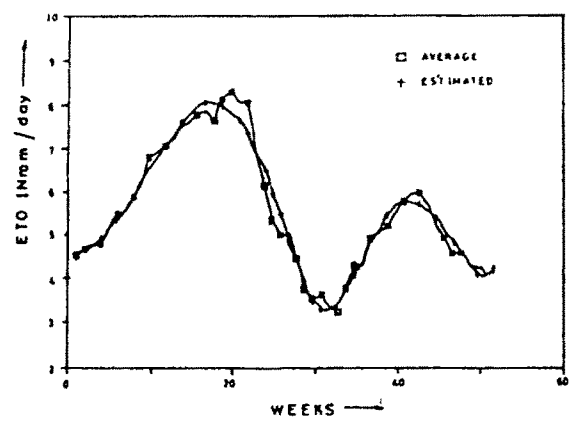


FIG.(e) ETO FOR JUNAGADH

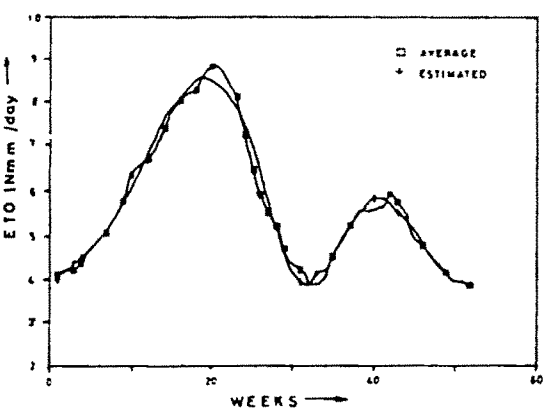


FIG (f) ETO FOR GUJARAT

FIG: 8.1 - AVERAGE ETO FOR ALL STATIONS AND REGIONAL AVERAGE.

8.2.4 A multiple regression analysis is carried out between the measured meteorological parameters viz. air temperature, humidity, sunshine and wind velocity with calculated average values of ETo. Finally an equation in the following form is derived using tables 6.6 and 7.13 for whole region.

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

Where

ETo = reference crop evapotranspiration in mm/ day

C = Additive constant

T = Mean temperature in degree celcius (long normal mean temperature)

n = Observed sunshine hours in a day

Rh = Mean relative humidity in percentage

U = Wind velocity in km/hr at 2 m height

C_1, C_2, C_3, and C_4 are multiplying constants for temperature, sunshine, relative humidity and wind velocity respectively.

As discussed above two equations are developed to take care of two peak pattern of the curve and are given as under.

For 1 to 33 weeks,

$$ETo = 0.283*T + 0.159*n - 0.065*RH + 0.094*U \quad ..(1)$$

For 33 to 52 weeks

$$ETo = 0.218*T + 0.106*n - 0.003*RH - 0.244*U \quad ..(2)$$

These equations are developed as a regional relationship for estimation of reference crop evapotranspiration. The coefficient of correlation is 0.996 for equation (1) and 0.977

for equation (2) which shows a good correlation between climatic variables and average reference crop evapotranspiration. These euations are quite useful for broad scale planning and ETo estimates for whole region. While estimating ETo for a particular sub region, with available data of that area, correction factors are required. For the five regions under study correction factors are as under.

Dantiwada and Vadaodara	0.97
Anand	0.95
Rajkot	1.09
Junagadh	1.00

8.2.5 The developed equations require four climatic variables for estimating ETo. Another attempt is made to develop equation for estimation of ETo using one or more measured climatic variables. Initially single parameters are tried and it was observed that with one parameter the value of coefficient of correlation is in the range of 0.20 to 0.80 except for pan evaporation. This is due to several interfering factors which affect the ETo. Thereafter two parameters are used in combination and it was found that with temperature and sunshine the value of ETo matches with the average values. The coefficient of correlation also improves and reaches upto 0.90. Considering additional factor of humidity in the equation much improvement in the results is not achieved. The variation pattern of temperature and ETo for entire year is almost identical except monsoon period during which ETo curve is supressed. This may be due to lowest values of sunshine

during that period. This leads to develop the equation for estimatng ETo as a function of temperature and sunshine.

The equations are developed using temperature and sunshine data from table 6.6 and ETo data from table 7.13. The derived equations in two parts suit best for the region under study and are given as under.

For 1 to 33 weeks,

$$ETo = 2.63 + 0.00055 * T^2 * n \quad ..(3)$$

For 33 to 52 weeks,

$$ETo = 2.63 + 0.00043 * T^2 * n \quad ..(4)$$

ETo, T and n have same meaning as mentioned above.

These equations are reliable and accurate for estimation of reference crop evapotranspiration for whole region as the correlation coefficients achived are 0.99 and 0.95 for equation (3) and (4) respectively. However for rabi season (Oct to March), ETo values are requaired to be reduced by 5 percent. Following correction factors are required to be applied while using these equations.

Dantiwada	1.00
Anand and Vadodara	0.96
Rajkot and Junagadh	1.05

8.2.6 Measured evaporation from a shallow pan of water is one of the oldest and most common methods of estimating ETo. The principal atmospheric variables affecting the evaporation are related to reference crop evapotranspiration. Moreover the pattern of curves for pan evaporation and evapotranspiration looks identical in our study. A

correlation have been developed between observed values of pan evaporation and calculated values of ETo using table 6.6 and 7.13. A simple relation is as under.

For 1 to 33 weeks,

$$ETo = 1 + 0.65 * E_{pan} \quad ..(5)$$

For 33 to 52 weeks,

$$ETo = -0.45 + E_{pan} \quad ..(6)$$

Where,

ETo = Reference crop evapotranspiration in mm/day

E_{pan}= Evaporation from class A open pan in mm/day

A good correlation have been observed with a correlation coefficient of 0.99 and 0.94 for equation (5) and (6) respectively. As the ETo is a function of climatic parameter, the correction factors are necessry to be applied for different climatological area. Therefore in this case also following correction factors are suggested for various stations for the use of equations (5) and (6).

Dantiwada	0.95
Anand	1.19
Vadodara	1.12
Rajkot	0.87
Junagadh	0.93

8.3 RELATIONSHIP BASED ON WEEKS

8.3.1 Another attempt has been made to simplify the procedure further using ETo calculated for five stations by six methods as discussed in para 8.2.2. Figure 8.1 (a to f) shows the values of ETo for Dantiwada, Anand, Vadodara,

Rajkot and Junagadh stations and for whole region. Looking to the curve developed, it can be concluded that the ETo follows a specific variation throughout the year as a function of a specific day of a year. Thus ETo is analysd as a function of week of a year. Further average values of various climatic factors do not show a significant variation for a given week of the year.

8.3.2 Looking to the two peak pattern of curve, analysis is carried out in two parts for best fit curve and equations are developed for all the stations and for the regions accordingly.

For developing week based relationship various alternative using least square technique were tried. Finally a five degree polynomial equation has been developed which fits best. Reccomended relationship is as under.

$$ETo = Co + C1 * W + C2 * W^2 + C3 * W^3 + C4 * W^4 + C5 * W^5$$

or

$$ETo = Co + \sum_{n=1}^{n} Cn * W^n$$

Where

ETo = Evapotranspiration of a reference crop in mm/day

W = Standard Weeks of the year (0 < w <= 52)

Co = Additive constant

C1, C2, C3, C4 and C5 are multiplying constants

n varies from 1 to 5

Cn = Constant varying with 'n'

Values of constant for the five stations and for the

regional relationships are as shown in Table 8.1. As the analysis is carried out for two peak patterns, two best fit curves are used as under :

(i) For 1 to 33 weeks

(ii) For 33 to 52 weeks

Tharefore values for constants are given separately for 1 to 33 weeks and 33 to 52 weeks.

Table 8.1

Constants for equation 7

Station	Constant					
	Co	C1	C2	C3	C4	C5
Dantiwada						
1 to 33	3.712	0.141	-0.027	0.0061	-0.00031	$4.4 * 10^{-6}$
33 to 52	3728.6	-453.7	21.81	-0.5178	0.00607	$2.82 * 10^{-5}$
Anand						
1 to 33	3.373	0.296	-0.051	0.0074	-0.00035	$5.1 * 10^{-6}$
33 to 52	1808.8	-214.3	0.10	-0.2293	0.00259	$1.15 * 10^{-6}$
Vadodara						
1 to 33	3.818	0.321	-0.061	0.0084	-0.000395	$5.64 * 10^{-6}$
33 to 52	5547.2	-654.4	30.59	-0.708	0.00812	$-3.69 * 10^{-5}$
Rajkot						
1 to 33	3.789	0.386	-0.08	0.0106	-0.00048	$6.72 * 10^{-6}$
33 to 52	-119.2	12.15	-0.562	0.0152	-0.00022	$1.32 * 10^{-6}$
Junagadh						
1 to 33	4.328	0.152	-0.013	0.0038	-0.000215	$3.55 * 10^{-6}$
33 to 52	92.3	-1.43	-0.497	-0.0278	-0.00054	$3.56 * 10^{-6}$
Regional Average						
1 to 33	3.804	0.259	-0.046	0.0073	-0.00035	$5.09 * 10^{-6}$
33 to 52	2211.5	-262.3	12.27	-0.2824	0.0032	$1.43 * 10^{-5}$

8.4 FIELD CORRELATION

8.4.1 Summarising above paragraphs it can be concluded that the developed regional relationship based on meteorological parameters can be used reliably for the regions under considerations. The results from these relationships have been evaluated with reference to actual lysimeter measurements performed in the same area. The observed ET was obtained by the experiments on Mug at Dantiwada, Groundnut, Cotton, Tobacco and Maize at Anand and Groundnut and Bajara at Rajkot. Table 5.4 gives observed values of evapotranspiration from a pair of lysimeters, for the crops and their period of sowing/harvesting. Values of reference crop evapotranspiration are calculated for Dantiwada, Anand and Rajkot using equation (3) and (4) based on temperature and bright sunshine hours. Necessary corrections were applied for the values of rabi season. These data are used to compare the observed and calculated ET values. Using FAO paper 24, crop factor (Kc) values are worked out for Bajara, Groundnut, Cotton, Tobacco, Mug and Maize for their growing period. The values worked out by FAO are adjusted according to length of growing season and time of planting. Using the ETo calculated for Dantiwada, Anand and Rajkot. Evapotranspiration for each crop is calculated as under:

$$ETcrop = ETo * Kc$$

Where Kc of a paricular crop for respective period is used. Thus observed and calculated values of evapotranspiration are available as under.

Station	Crop	Year
1. Dantiwada	Mug	1990,1991
2. Anand	Groundnut	1986.1988
	Cotton	1982,1983
	Tobacco	1979,1980,1981
	Maize	1989
3. Rajkot	Bajara	1980.1982,1984 1988,1990
	Groundnut	1981,1983,1989

The comparision of observed and calculated evapotranspiration values is shown in table 8.2 to 8.8.

8.4.2 The average weekly values of observed and calculated evapotranspiration were tabulated into cummulative form starting from the date of sowing of a paricular crop for respective year. The crops are grown in different seasons. Considering this aspect the data is further analysed on seasonal basis. Using the cummulative values of observed and caculated evapotranspiration of crops, curves are drawn as shown in figures 8.2 to 8.11. For Groundnut at Rajkot due to different dates of sowing, two differnt graphs are drawn. Likewise for Groundnut and Tobacco at Anand two different curves are plotted. The calculated values of evapotranspiration are compared with observed values and it is found that the deviations are within acceptable range.

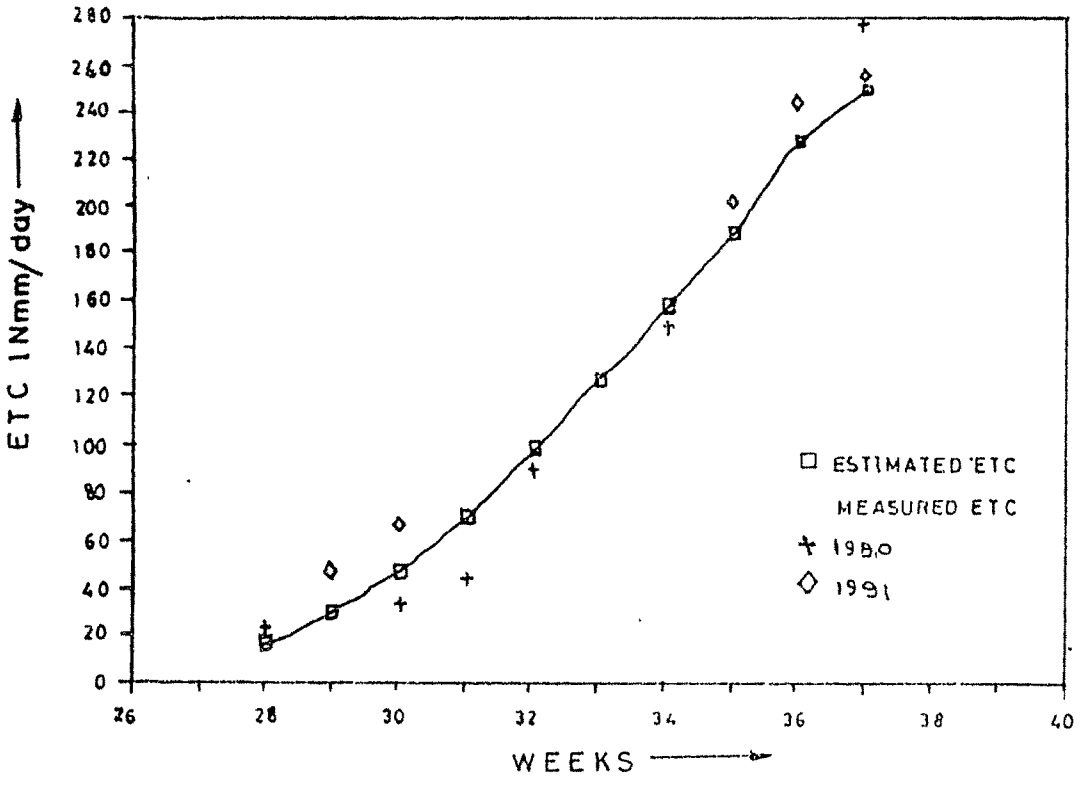


FIG: 8.2 – COMPARISION OF ETC FOR MUG AT DANTIWADA

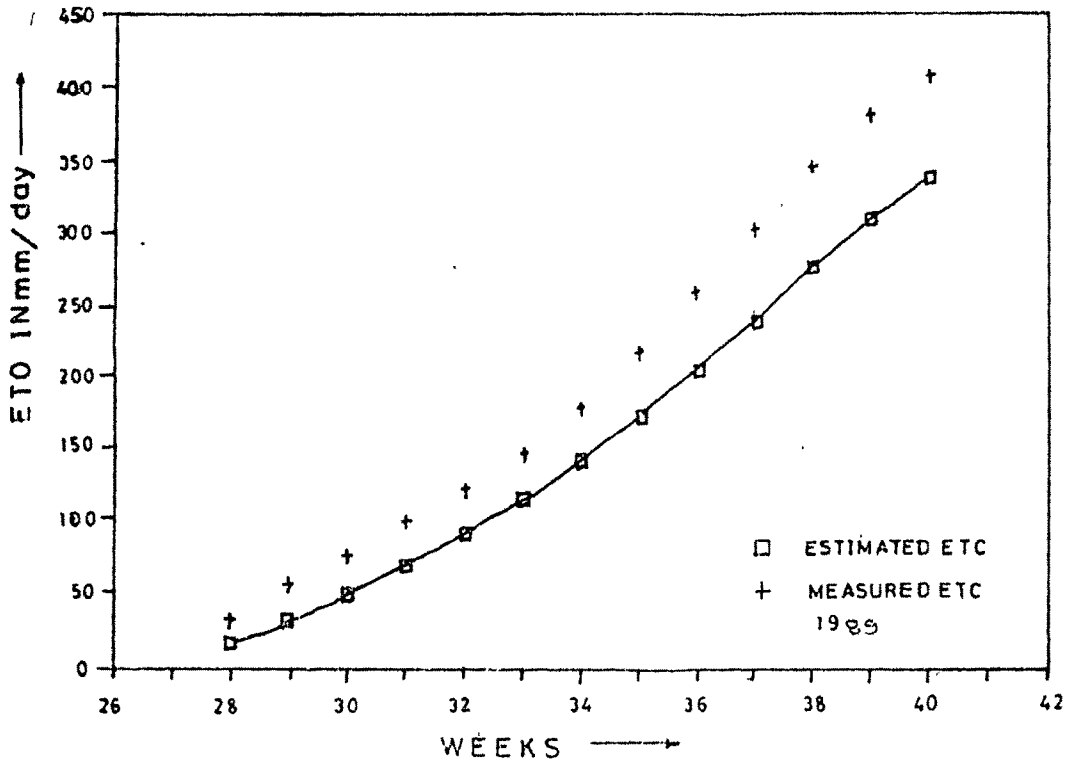


FIG.8.3-COMPARISION OF ETC FOR MAIZE AT ANAND

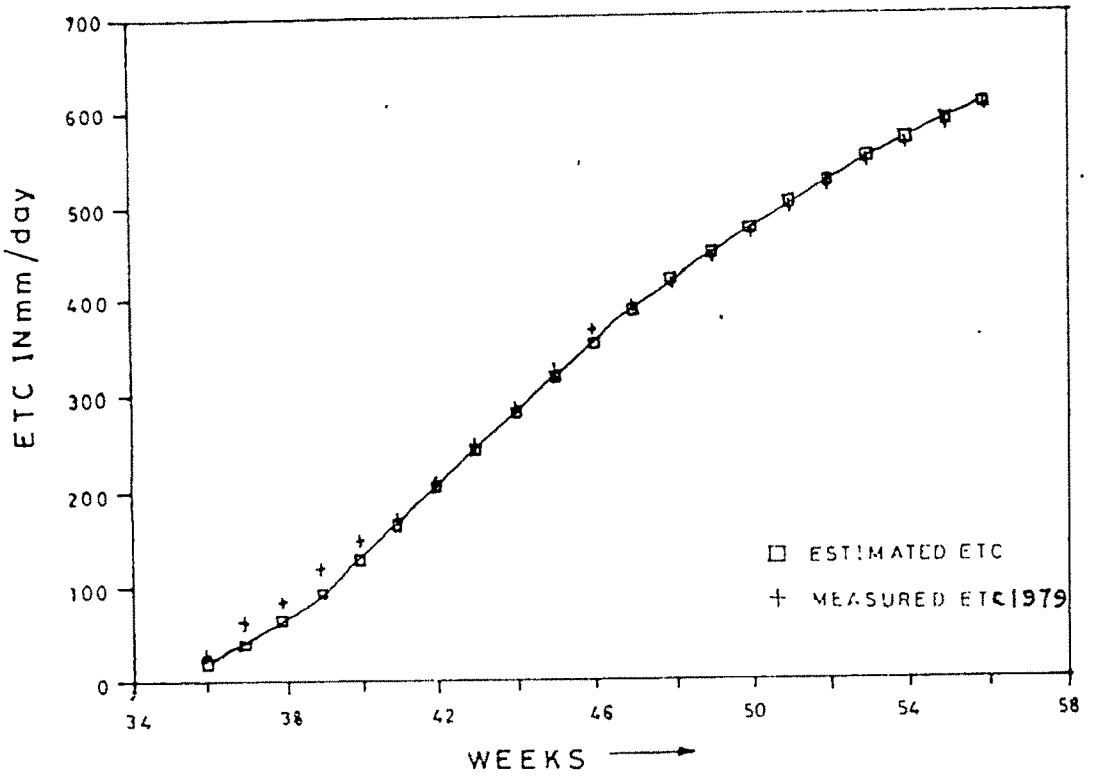


FIG 8.4-COMPARISION OF ETC FOR TOBACCO AT ANAND

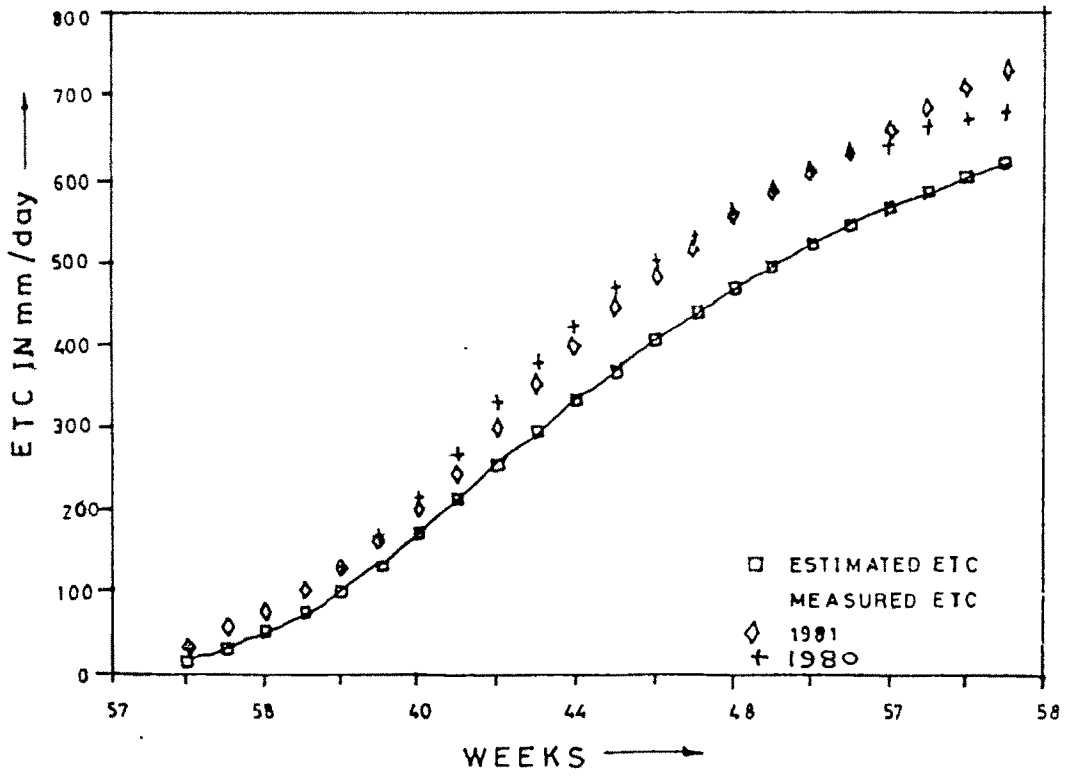


FIG: 8.5-COMPARISION OF ETC FOR TOBACCO AT ANAND

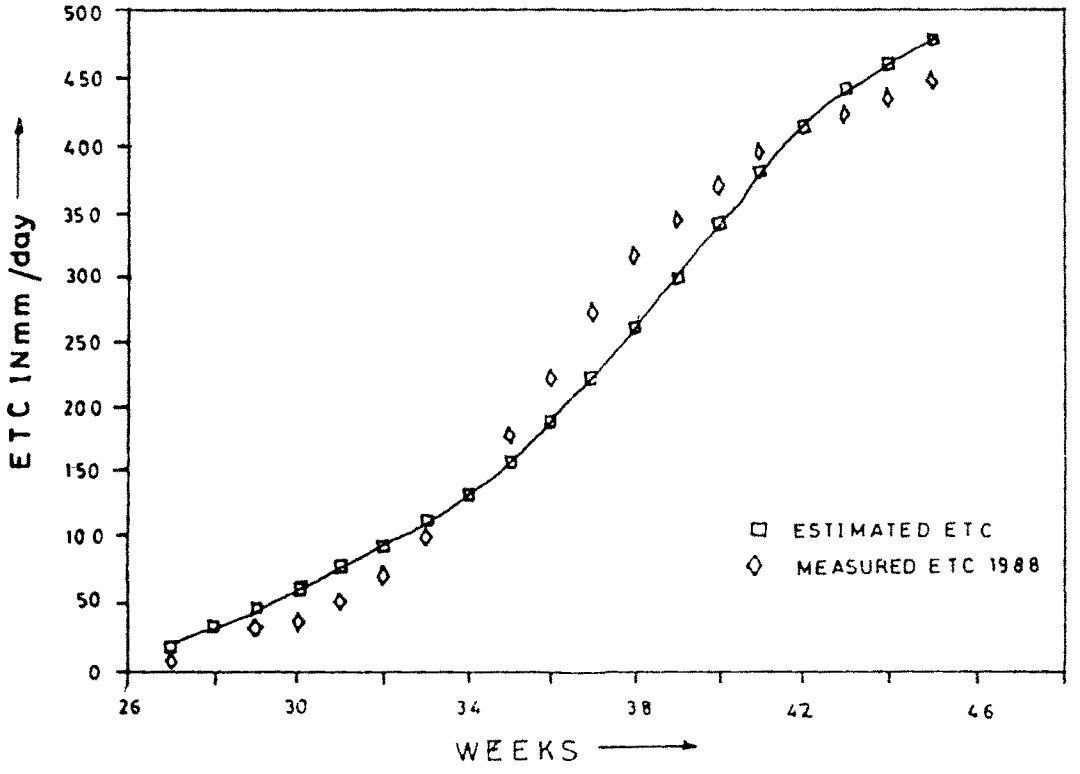


FIG.8.6-COMPARISION OF ETC FOR GROUND NUT AT ANAND

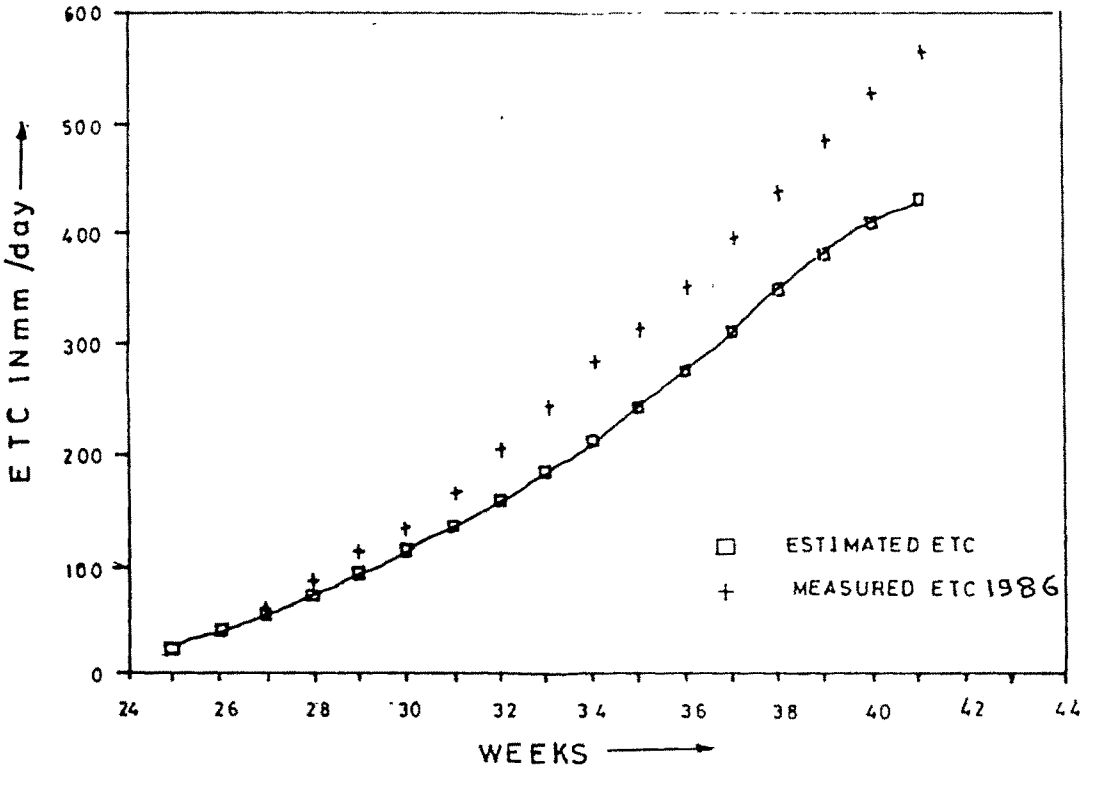


FIG.8.7-COMPARISION OF ETC FOR GROUND NUT AT ANAND

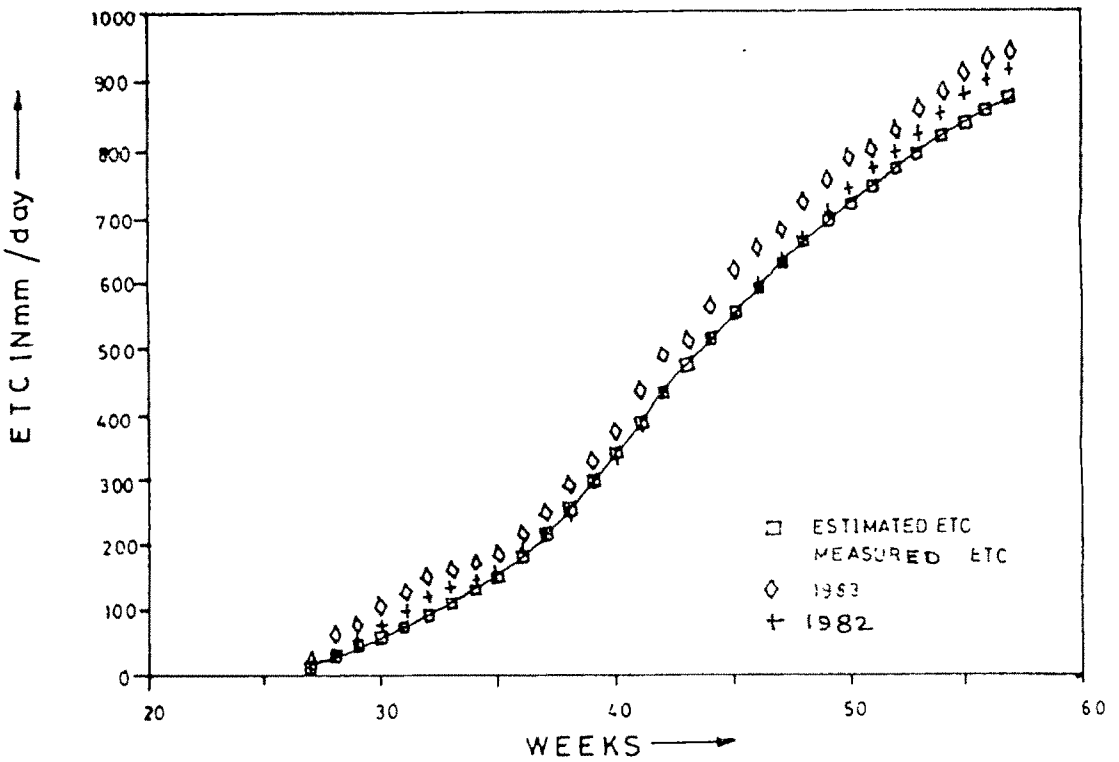


FIG.8.8-COMPARISION OF ETC FOR COTTON AT ANAND

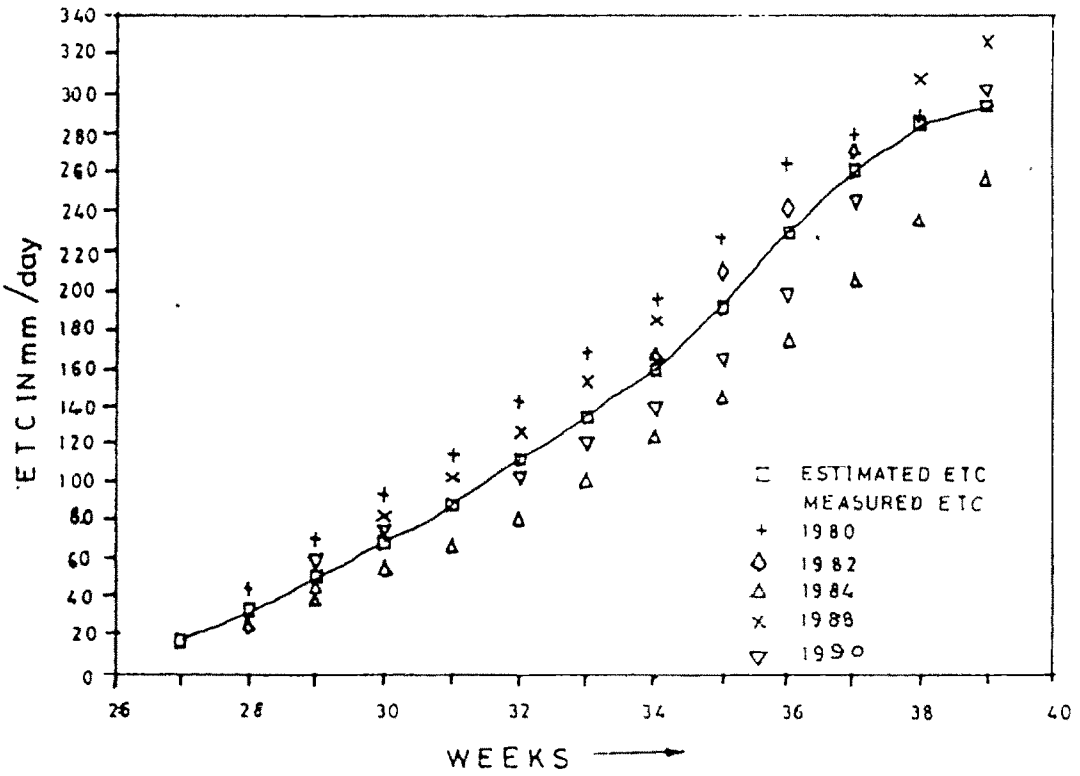


FIG.8.9-COMPARISION OF ETC FOR BAJARA AT RAJKOT

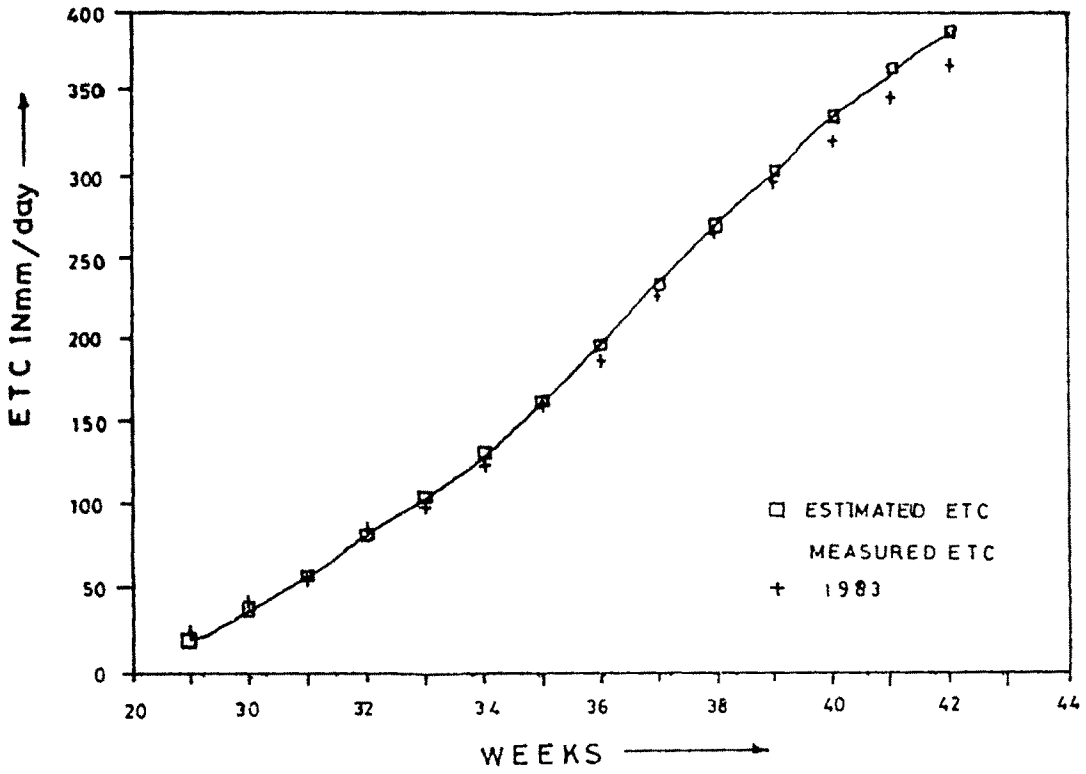


FIG. 8.10-COMPARISION OF ETC FOR GROUNDNUT AT RAJKOT

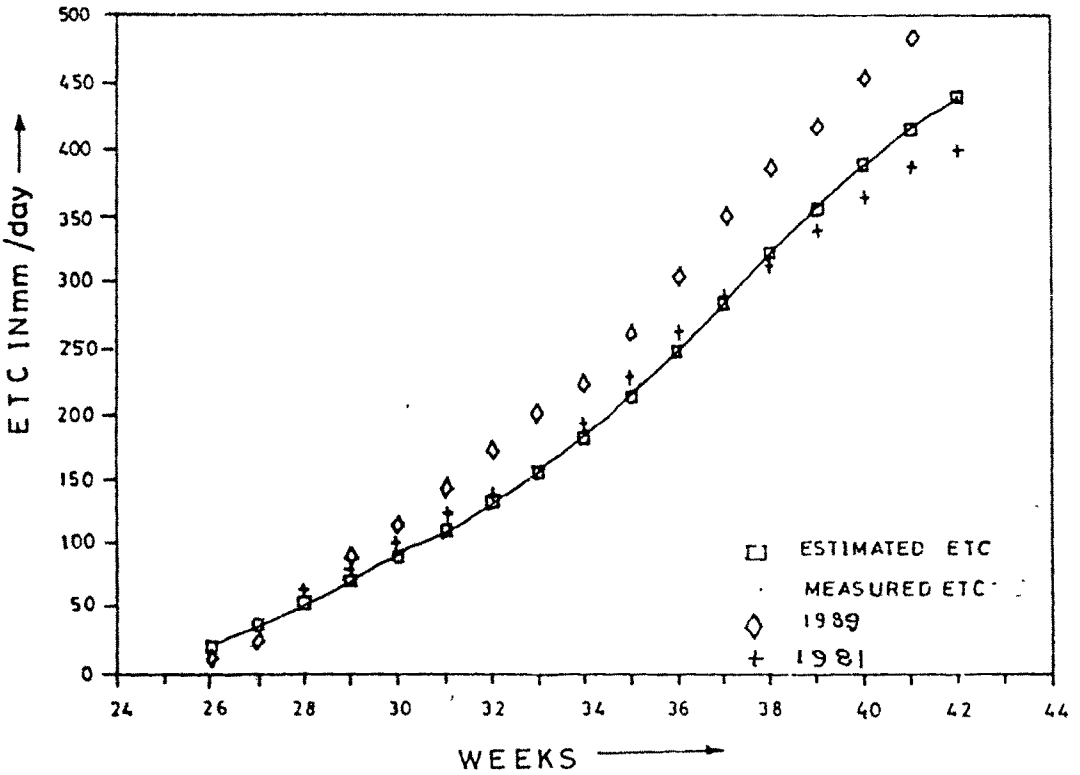


FIG. 8.11- COMPARISION OF ETC FOR GROUND NUT AT RAJKOT

TABLE 8.2

COMPARISION OF ETc FOR MUG AT DANTIWADA

WEEKS	ETo T-n	Kc	ETc T-n	OBSSERVED ETc 90	91
28	6.15	0.38	2.34	3.36	2.80
29	5.48	0.38	2.08	0.80	4.17
30	4.46	0.55	2.45	0.71	2.75
31	4.62	0.71	3.28	1.59	1.15
32	4.73	0.88	4.16	6.50	2.79
33	3.97	1.05	4.17	5.80	4.48
34	4.01	1.05	4.21	2.70	4.80
35	4.25	1.05	4.46	5.11	5.90
36	5.29	1.05	5.55	6.46	6.08
37	5.46	0.55	3.00	6.66	1.62
38	6.01			4.25	0.69

TABLE 8.3

COMPARISION OF ETc FOR GROUNDNUT AT ANAND

WEEKS	ETo T-n	Kc	ETc T-n	OBSERVED ETc 86	88
25	6.27			2.00	
26	5.42			3.30	
27	5.03	0.48	2.41	2.90	1.40
28	4.82	0.48	2.31	3.80	2.60
29	4.42	0.48	2.12	4.10	0.80
30	4.55	0.48	2.18	2.70	0.40
31	4.14	0.56	2.32	4.60	2.20
32	3.86	0.64	2.47	5.90	2.70
33	3.88	0.72	2.79	5.20	4.50
34	3.84	0.81	3.11	5.70	4.10
35	4.34	0.89	3.86	4.20	6.60
36	4.71	0.97	4.57	5.40	6.60
37	4.93	1.05	5.18	6.40	7.40
38	5.34	1.05	5.61	5.80	5.90
39	5.45	1.05	5.72	7.20	3.80
40	5.87	1.05	6.16	6.30	3.90
41	5.67	1.05	5.95	5.30	3.60
42	5.72	0.89	5.09		2.40
43	5.51	0.72	3.97		1.90
44	5.30	0.55	2.92		1.70
45	5.15	0.50	2.58		1.70
46	4.98				1.70

TABLE 8.4

COMPARISION OF ETc FOR TOBACCO AT ANAND

WEEKS	ETo T-n	KC	ETc T-N	OBSERVED ETc 79	80	81
34	3.84	0.52	2.00		3.78	4.50
35	4.34	0.52	2.26		4.00	3.50
36	4.71	0.62	2.92	3.60	3.14	2.70
37	4.93	0.71	3.50	5.10	3.97	3.60
38	5.34	0.81	4.33	3.20	4.50	4.70
39	5.45	0.91	4.96	4.60	4.94	4.70
40	5.87	1.00	5.87	4.80	5.94	5.20
41	5.67	1.10	6.24	3.40	7.47	6.30
42	5.72	1.10	6.29	5.19	8.47	8.20
43	5.51	1.10	6.06	5.50	7.21	7.40
44	5.30	1.10	5.83	5.70	6.39	6.20
45	5.15	1.10	5.67	5.70	6.83	6.60
46	4.98	1.10	5.48	5.60	4.80	6.10
47	4.65	1.10	5.12	2.70	3.86	4.70
48	4.53	1.10	4.98	4.30	4.67	5.30
49	4.30	1.03	4.43	4.20	4.56	4.50
50	4.19	0.96	4.02	3.50	3.51	3.80
51	4.20	0.89	3.74	3.70	2.60	3.10
52	4.10	0.82	3.36	3.80	1.91	3.60
01	4.46	0.75	3.35	2.90	2.14	4.00
02	4.50	0.68	3.06	2.90	1.73	3.40
03	4.47	0.61	2.73	2.50	0.95	2.90
04	4.53			2.80	1.12	

Table 8.5

COMPARISION OF ETc FOR COTTON AT ANAND

WEEKS	ETo T-n	Kc	ETc T-n	OBSERVED 82	ETc 83
27	5.03	0.48	2.41	2.70	3.70
28	4.82	0.48	2.31	2.50	3.30
29	4.42	0.48	2.12	2.80	3.90
30	4.55	0.52	2.37	3.10	4.00
31	4.14	0.55	2.28	2.80	4.40
32	3.86	0.62	2.39	3.40	4.00
33	3.88	0.69	2.68	1.90	3.70
34	3.84	0.77	2.96	1.70	3.30
35	4.34	0.85	3.69	1.90	3.60
36	4.71	0.92	4.33	4.70	4.30
37	4.93	1.00	4.93	3.80	5.50
38	5.34	1.07	5.71	4.60	5.00
39	5.45	1.10	6.00	5.80	5.90
40	5.87	1.10	6.46	5.70	7.60
41	5.67	1.15	6.52	6.80	7.40
42	5.72	1.15	6.58	6.90	5.20
43	5.51	1.20	6.61	5.50	7.10
44	5.30	1.20	6.36	5.80	8.60
45	5.15	1.20	6.18	6.40	7.80
46	4.98	1.20	5.98	5.50	6.90
47	4.65	1.15	5.35	4.90	7.50
48	4.53	1.15	5.21	5.60	7.50
49	4.30	1.10	4.73	5.20	7.10
50	4.19	1.05	4.40	4.80	4.80
51	4.20	1.00	4.20	4.20	5.00
52	4.10	0.95	3.90	3.80	5.30
01	4.46	0.90	4.01	4.40	4.70
02	4.50	0.82	3.69	4.00	4.70
03	4.47	0.75	3.35	4.00	4.50
04	4.53	0.70	3.17	3.70	3.40
05	4.67	0.65	3.04	2.40	2.70

TABLE 8.6

COMPARISION OF ETc FOR MAIZE AT ANAND

WEEKS	ETo T-n	Kc	ETc T-n	OBS ETC 89
28	4.82	0.48	2.31	4.30
29	4.42	0.48	2.12	3.60
30	4.55	0.59	2.68	2.80
31	4.14	0.71	2.94	3.40
32	3.86	0.84	3.24	3.20
33	3.88	0.95	3.69	3.60
34	3.84	1.05	4.03	4.50
35	4.34	1.05	4.56	5.70
36	4.71	1.05	4.95	6.00
37	4.93	1.05	5.18	6.30
38	5.34	1.05	5.61	6.20
39	5.45	0.89	4.85	4.80
40	5.87	0.72	4.23	3.80
41	5.67	0.55	3.12	

TABLE 8.7

COMPARISION OF ETc FOR BAJARA AT RAJKOT

WEEKS	ETo T-n	Kc	ETc T-n	OBSERVED ETc 80	82	84	88	90
26	5.73							
27	5.17	0.44	2.27	2.80	2.70	1.90	2.20	2.00
28	4.83	0.44	2.13	3.40	1.80	1.80	2.30	2.70
29	4.55	0.52	2.37	3.80	1.60	1.80	3.50	3.60
30	4.23	0.59	2.50	3.30	2.90	2.20	3.60	2.20
31	4.10	0.67	2.75	3.00	3.80	1.80	3.00	1.50
32	4.26	0.75	3.20	4.20	3.70	2.00	3.40	2.70
33	3.69	0.82	3.03	3.60	2.70	2.90	3.90	2.60
34	3.85	0.90	3.47	3.80	4.70	3.30	4.40	2.60
35	4.55	0.97	4.41	4.30	5.90	3.10	3.80	3.60
36	4.86	1.02	4.96	5.20	4.30	4.10	4.50	4.70
37	5.23	0.80	4.18	2.20	4.30	4.40	4.60	6.40
38	5.25	0.55	2.89	1.40	2.40	4.10	4.50	5.80
39	5.26	0.30	1.58	0.90		2.80	2.80	2.40

TABLE 8.8

COMPARISION OF ETc FOR GROUNDNUT AT RAJKOT

WEEKS	ETo T-n	Kc	ETc T-n	OBSERVED ETc 81	83	89
26	5.73	0.44	2.52	2.40		1.90
27	5.17	0.44	2.27	2.90		2.00
28	4.83	0.48	2.32	3.50		4.00
29	4.55	0.52	2.37	2.50	3.30	4.80
30	4.23	0.60	2.54	2.70	2.50	3.30
31	4.10	0.68	2.79	3.50	2.20	4.40
32	4.26	0.76	3.24	2.10	3.80	4.20
33	3.69	0.84	3.10	2.50	2.20	4.30
34	3.85	0.92	3.54	5.20	3.40	3.20
35	4.55	0.96	4.37	5.50	5.30	5.20
36	4.86	0.96	4.67	4.80	3.80	6.20
37	5.23	0.96	5.02	3.50	5.90	6.30
38	5.25	0.96	5.04	3.70	5.40	5.20
39	5.26	0.85	4.47	3.60	4.60	4.60
40	5.85	0.75	4.39	3.50	3.30	5.10
41	5.82	0.65	3.78	3.30	3.70	4.40
42	5.90	0.55	3.25	1.70	2.90	