Appendix I

Structure of WEAP Model

The Water Evaluation and Planning (WEAP) software is used as a simulation and evaluation tool to assess the performance of possible water resource management alternatives, under different conditions. WEAP is an integrated and comprehensive planning framework which uses: scenario analyses in understanding the effects of different development choices; demand-management capability; and environmental assessment capability. It operates on the basic principles of water balance accounting. WEAP is applicable to municipal and agricultural systems, single sub basins or complex river systems. WEAP model facilitates in indicator based decision making with regard to water use, under varied environmental, social, economic, agricultural, and climate change dimensions. The supply and water demand processes can be simulated under different climate scenarios. The main target of the study was limited to account for the groundwater and surface water use for irrigation purpose. WEAP applications generally involve the following steps

- Defining the Study problem, including setting up the time frame, spatial boundary, system components and configuration of the problem.
- Establishing the Current Accounts which provide a snapshot of actual water demand, pollution loads, resources and supplies for the system.
- Constructing various scenarios based on alternative sets of future trends, based on policies, costs, technological development and other factors that affect demand, pollution, supply and hydrology.
- Evaluating the scenarios with regard to use of groundwater and canal water, yield, benefits, and environmental impacts.

The scenarios analysis can addresses questions, such as: population growth, groundwater fully exploited, introducing water conservation techniques, implementing water-recycling program, implementing efficient irrigation techniques, change in cropping pattern, change in agricultural crops, effect of climate change on the hydrology. These scenarios may be viewed simultaneously in the results for easy comparison of their effects on the water system.

WEAP calculates a water and pollution mass balance for every node and link in the system on a monthly time step. WEAP operates on a monthly time step, from the first month of the Current Accounts year through the last month of the last scenario year.

Each month the calculations follow this order:

1. Annual demand and monthly supply requirements for each demand site and flow requirement. Catchment potential evapotranspiration, and runoff and infiltration.
2. Inflows and outflows of water for every node and link in the system. This includes calculating withdrawals from supply sources to meet demand.

WEAP model has various modules to compute: (1) Irrigation demands only method (FAO Crop Requirements Method), (2) Rainfall Runoff Method (FAO Crop Requirements Method), (3) Rainfall Runoff Method (Soil Moisture Method), and (4) MABIA Method (FAO -56, Dual Kc, Daily). In this study we have used MABIA Method.

The MABIA Method is a daily simulation of transpiration, evaporation, irrigation requirements and scheduling, crop growth and yields, and includes modules for estimating reference evapotranspiration and soil water capacity. It was derived from the MABIA suite of software tools, developed at the Institut National Agronomique de Tunisie by Dr. Ali Sahli and Mohamed Jabloun. For more information about MABIA and to download standalone versions of the software, visit http://www.mabia-agrosoftware.net.

The MABIA Method uses the 'dual' K_c method, as described in FAO Irrigation and Drainage Paper No. 56 (Spanish version of FAO 56), whereby the K_c value is divided into a 'basal' crop coefficient, K_{cb}, and a separate component, K_e, representing evaporation from the soil surface. The basal crop coefficient represents actual ET conditions when the soil surface is dry but sufficient root zone moisture is present to support full transpiration. In this way, MABIA is an improvement over CROPWAT, which use a single K_c method, and hence, does not separate evaporation and transpiration.

Although the time step for MABIA is daily, the time step for the rest of WEAP analysis does not need to be daily (although it can be daily). The steps in the MABIA calculations are as follows:

(1) Reference Evapotranspiration (ETref)

Reference crop evapotranspiration or reference evapotranspiration, denoted as ETo or ETref, is the estimation of the evapotranspiration from the "reference surface." The calculation methods implemented in the MABIA Method are those of the FAO Penman-Monteith equation as outlined in the FAO Irrigation and Drainage Paper 56.

(2) Soil Water Capacity

The MABIA method requires data on water holding capacity at field capacity and wilt point, for each catchment land use. In using Soil Profiles, you can enter field capacity and wilt point directly, or choose a texture class from the Soil Library.

(3) Basal Crop Coefficient (K_{cb})

The MABIA Method uses the 'dual' K_c method, as described in FAO Irrigation and Drainage Paper No. 56, whereby the K_c value is divided into a 'basal' crop coefficient, K_{cb}, and a separate component, K_e, representing evaporation from the soil surface. The basal crop coefficient represents actual ET conditions when the soil surface is dry but sufficient root zone moisture is present to support full transpiration.

(4) Potential and Actual Crop Evapotranspiration (ET_c)

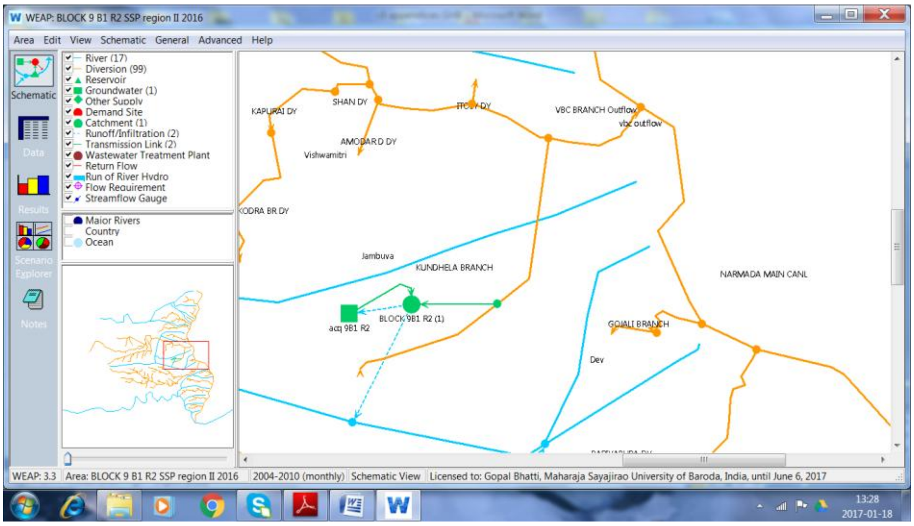
The potential crop evapotranspiration is estimated under standard field conditions. As precipitation and irrigation amounts are often not sufficient to supply the full ET_c requirement the soil water content in the root zone is reduced to levels too low to permit plant roots to extract the full ET_c amount. Under these conditions, water stress is said to occur, and ET_a is less than ET_c. The reduction in ET_a can be estimated using a daily soil water balance.

(5) Irrigation

Irrigation is required when rainfall is insufficient to compensate for the water lost by evapotranspiration. The primary objective of irrigation is to apply water at the right period and in the right amount. An irrigation schedule specifies the timing (which day) and amount (depth) of irrigation. There are various methods available to determine both the timing and amount of irrigation. The optimal irrigation schedule and amount would use % of RAW (100% of RAW) as the trigger method, and % of Depletion (100% of Depletion) as the irrigation amount method, which would apply irrigation at the last moment before crop stress would occur, and irrigate just enough to get back up to field capacity. However, in reality, it will be difficult for a farmer to know exactly when depletion reaches the RAW threshold

(6) Yield Response to Water Shortage

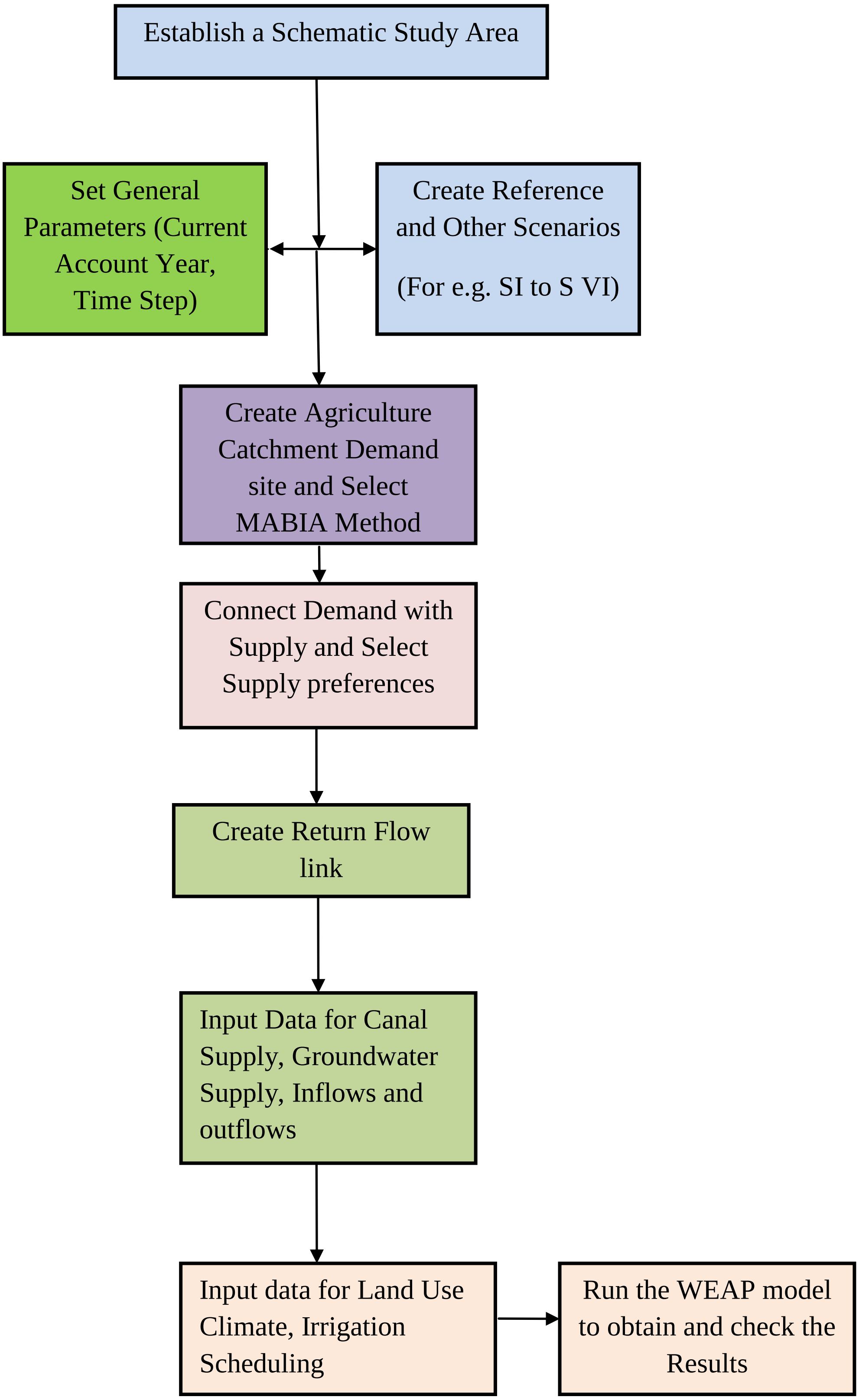
Water deficits in crops, and the resulting water stress on the plant, have an effect on crop evapotranspiration and crop yield. The relationship between crop yield and water supply can be determined when crop water requirements and actual crop water use, on the one hand, and maximum and actual crop yield on the other, can be quantified. In the FAO 56 approach, the response of yield to water supply is quantified by the yield response factor (K_y). FAO Irrigation and Drainage Paper No. 33 empirically derived yield-response factors (K_y) for individual growth stages (i.e. establishment, vegetative, flowering, yield formation, or ripening period) as well as for the total growing period. Yield response factor to water stress is taken from the Crop Library. However, if water stress cannot be considered as constant throughout the growing period but occurs with different magnitude at different periods of the growing season, the expected total relative yield fraction should be calculated at a smaller time step and aggregated for the season. In the MABIA method, relative yield fractions will be calculated on a daily time step, and the multiplicative product of the yield fractions from all days will be used as the relative yield fraction for the season. (For details and justification for this approach, see Dirk Raes, Sam Geerts, Emmanuel Kipkorir, Joost Wellens, and Ali Sahli, Simulation of yield decline as a result of water stress with a robust soil water balance model. *Agricultural Water Management*, 81: 335-357, 2006.)



All menus along with Schematic view of Study Area has been shown above with print screen shot

Appendix II

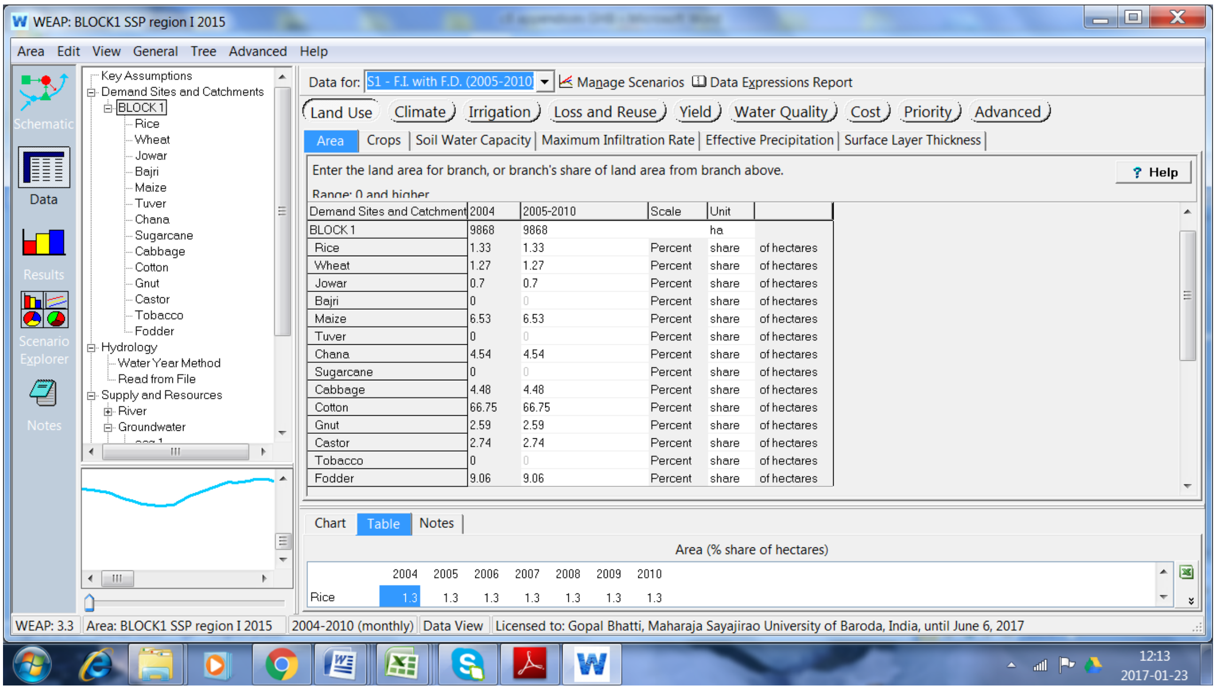
Flow chart of WEAP Model



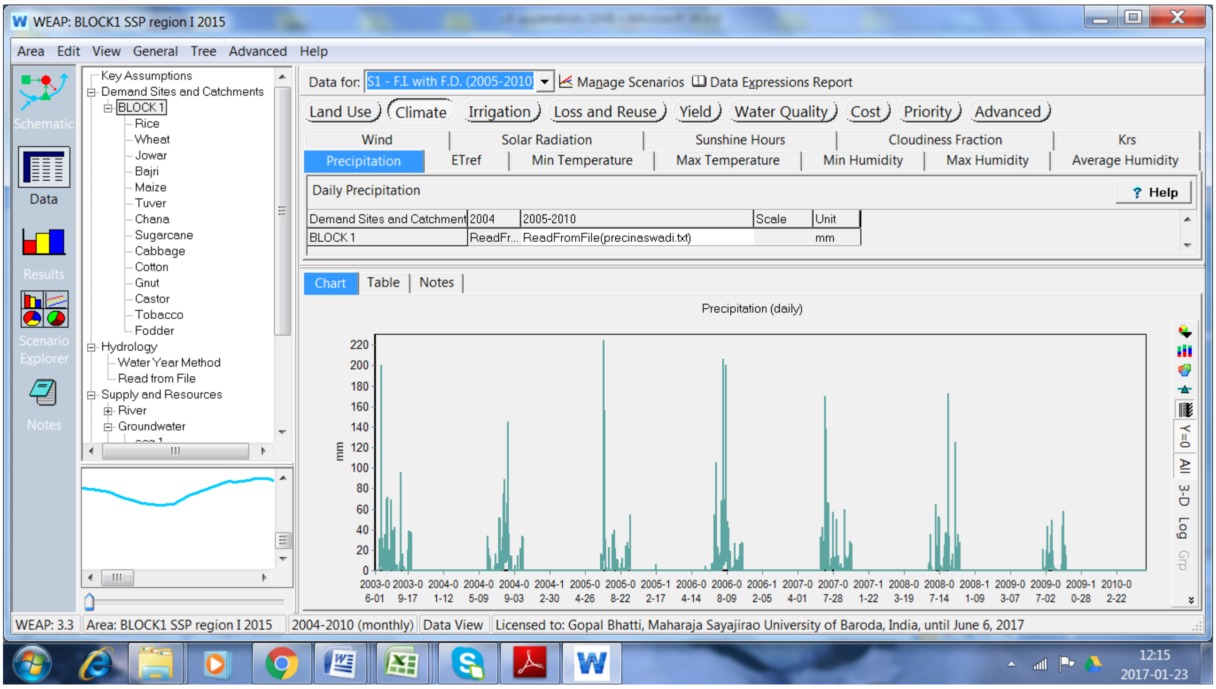
Appendix III

Input Files

Input for Land Use



Input for Climate



1. Input data for e.g. Block 1 for Rainfall: ReadFromFile(precinaswadi.txt)

Precipitation (daily) (mm)
Scenario: S1 - F.I. with F.D.

2003-06-01	0
2003-06-02	0
2003-06-03	0
2003-06-04	0
.	.
.	.
2010-05-30	0
2010-05-31	0

2. Input data for e.g. Block 1 for Maximum temperature: ReadFromFile(maxtempnaswadi.txt)

Max Temperature (daily) (C)
Scenario: S1 - F.I. with F.D.

	BLOCK 1
2003-06-01	42.5
2003-06-02	41.5
2003-06-03	41
2003-06-04	40.5
2003-06-05	38.5
2003-06-06	38
.	.
.	.
2010-05-30	40
2010-05-31	40

3. Input data for Block 1 for Irrigation Scheduling: Rice: S I - F.I. with F.D. (2005-2010)

IrrigationSchedule(1, Jul 1, Oct 23, Fixed Interval, 15, Fixed Depth, 200)

4. Input data for Block 1 for Canal Supply and from Groundwater Maximum Flow Volume (monthly) (Cumecs)

Scenario: S1 - F.I. with F.D.

	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03	Jan-04	Feb-04	Mar-04	Apr-04	May-04
from Withdrawal Node 1	0	0	0	0	0	6.928	6.928	6.928	6.928	6.928	6.928	0
from acq 1	0	0	0	0	0	0	0	0	0	0	0	0

Appendix IV

Few Calculations

BOX 1:

Example spreadsheet for calculating reference evapotranspiration (Ref_{ET}) by Modified Penman equation as per FAO-56

Equation in text or footnote as per FAO 56	Cell	Text, value, or formula
	A4	6
	B4	1
	C4	2009
	D4	26
	E4	38
Equation 9	F4	=(D4+E4)/2
	G4	48
	H4	56
	I4	3.332
Equation 47	J4	=I4*(4.87/(LN((67.8*$H$386)-5.42)))
	K4	3.332
	L4	9.400
Equation 13	M4	=(4098*(0.6108*(EXP((17.27*F4)/(F4+237.3)))))/((F4+237.3)^2)
Table 2.5	N4	=TRUNC(275*A4/9-30+B4)+IF(A4>2,-2,0)+IF(MOD(C4,4)=0,1,0)
Equation 23	O4	=1+(0.033*COS(2*3.14*N4/365))
Equation 24	P4	=0.409*SIN((2*3.14*N4/365)-1.39)
Equation 25	Q4	=ACOS(-TAN($E$391)*TAN(P4))
Equation 21	R4	=(24*60/3.14)*$E$390*O4*((Q4*SIN($E$391)*SIN(P4))+(COS($E$391)*COS(P4)*SIN(Q4)))
Equation 34	S4	=24*Q4/3.14
	T4	=L4/S4
Equation 35	U4	=(0.25+(0.5*T4))*R4
Equation 37	V4	=(0.75+(2*$E$389*10^-5))*R4
	W4	=U4/V4
Equation 38	X4	=(1-$E$392)*U4
Table 2.8	Y4	=$E$393*((E4+273.16)^4)
Table 2.8	Z4	=$E$393*((D4+273.16)^4)
Equation 11	AA4	=0.6108*EXP((17.27*D4)/(D4+237.3))
Equation 11	AB4	=0.6108*EXP((17.27*E4)/(E4+237.3))
Equation 17	AC4	=((AA4*H4/100)+(AB4*G4/100))/2
	AD4	=(AA4+AB4)/2
	AE4	=AD4-AC4
Equation 39	AF4	=((Y4+Z4)/2)*(0.34-(0.14*SQRT(AC4)))*((1.35*W4)-0.35)
Equation 40	AG4	=X4-AF4
Equation 6	AH4	=((0.408*M4*AG4)+($E$388*(900/(F4+273))*K4*AE4))/(M4+($E$388*(1+0.34*K4)))
	AI4	---------------
	AJ4	7.898
	AK4	=AJ4-AH4
	E386	90
	H386	10
Equation 7	E387	=101.3*(((293-0.0065*$E$386)/293)^5.26)

Equation 8	E388	=(0.665*10^-3)*$E$387
	E389	22.01
	E390	0.082
Equation 22	E391	=(3.14/180)*$E$389
	E392	0.23
	E393	=4.903*10^-9

SPREADSHEET 1:

Example Spreadsheet for Calculating Reference Evapotranspiration by Modified Penman Method as illustrated in FAO 56

Spreadsheet for calculating reference ET from A to K column for rows 1 to 6

	A	B	C	D	E	F	G	H	I	J	K
1	**SYMBOL >**			**Tmin**	**Tmax**	**Tmean**	**Rhmin**	**Rhmax**	**uz**	**u2**	**u2**
2	**Month**	**Day**	**DATE**	**Min. Temp.**	**Max. Temp.**	**Mean Temp**	**Min. Humidity.**	**Max. Humidity.**	**WS**	**FORMULA WS at 2m height**	**WEAP DATA WS at 2m height**
3			**UNIT >**	**°C**	**°C**	**°C**	**%**	**%**	**m/s**	**m/s**	**m/s**
4	6	1	2009	26	38	32	48	56	3.332	2.492	3.332
5	6	2	2009	26	38	32	48	56	4.443	3.323	4.443
6	6	3	2009	26	38	32	48	56	2.222	1.662	2.222

Spreadsheet continued for calculating reference ET from L to U columns for rows 1to 6

	L	M	N	O	P	Q	R	S	T	U
1	**n**	**Δ**	**J**	**dr**	**δ**	**ωs**	**Ra**	**N**	**n/N**	**Rs**
2	**BSS**	**Slope of saturation vapour pressure curve**	**No. of the day in year**	**Inverse relative distance earth-sun**	**solar declimation**	**sunset hour angle**	**Extraterrestrial radiation**	**Daylight hours**	**Relative sunshine duration**	**Solar radiation**
3	**hours**	**kPa/°C**	**-**	**-**	**rad**	**rad**	**MJ/m2 day**	**hours**	**-**	**MJ/m2 day**
4	9.400	0.269	152.000	0.971	0.385	1.735	39.886	13.262	0.709	24.106
5	9.500	0.269	153.000	0.971	0.387	1.736	39.896	13.271	0.716	24.254
6	10.800	0.269	154.000	0.971	0.389	1.737	39.905	13.279	0.813	26.204

Spreadsheet continued for calculating reference ET from V to AE columns for rows 1 to 6

	V	W	X	Y	Z	AA	AB	AC	AD	AE
1	**Rso**	**Rs/Rso**	**Rns**	**σ*Tmax K ^4**	**σ*Tmin K ^4**			**ea**	**es**	**VPD es-ea**
2	**Clear sky solar radiation**		**Net shortwave radiation**	**Max. absolute Temp.**	**Min. absolute Temp.**	**eo(Tmin)**	**eo(Tmax)**	**Actual vapour pressure**		**vapour pressure deficit**
3	**MJ/m2 day**	-	**MJ/m2 day**	**MJ/K3 m2day**	**MJ/K3 m2day**			**kPa**		**kPa**
4	29.932	0.805	18.562	45.962	39.271	3.361	6.625	2.531	4.993	2.462
5	29.940	0.810	18.675	45.962	39.271	3.361	6.625	2.531	4.993	2.462
6	29.947	0.875	20.177	45.962	39.271	3.361	6.625	2.531	4.993	2.462

Spreadsheet continued for calculating reference ET from AF to AK columns for rows 1 to 6

	AF	AG	AH	AI	AJ	AK
1	**Rnl**	**Rn**	**ETo**			
2	**Net longwave radiation**	**Net radiation**	**Reference Evapotranspiration**		**WEAP ET REF**	**DIFF WEAP ET AND CALCULATED ET**
3	**MJ/m2 day**	**MJ/m2 day**	**mm/day**		mm/day	
4	3.684	14.877	7.897		7.898	0.001
5	3.716	14.959	8.695		8.697	0.001
6	4.154	16.023	7.342		7.345	0.003

Spreadsheet continued for calculating reference ET from A to H columns for rows 385 to 393

	A	B	C	D	E	G	G	H
385			**PARAMETERS**	**SYMBOL**	**VALUE**	**UNIT**	**PARAMETERS**	**VALUE**
386			ALTITUDE		90	m	Wind Measurement height z	10
387			Atmospheric. Pressure	P	100.24066	kPa		
388			Psychrometric constant	γ	0.06666	kPa/°c		
389			Latitude		22.01			
390			Solar constant	Gsc	0.082	MJ/m2 min		
391			Latitude (rad)	Φ	0.3839522	radians		
392			Canopy reflection coefficient	α	0.23			
393			Stefan-boltzmann constant	σ	4.903E-09	MJ/K4 m2 day		

BOX 2:

Example spreadsheet for calculating Actual evapotranspiration (ET act) and an irrigation schedule

Equation in text or footnote as per FAO 56	Cell	Text, value, or formula
	A1	Example Spreadsheet For Calculating Actual Evapotranspiration (ET act) And An Irrigation Schedule
	P1	Computed Dates for stages:
	A2	Block 1
	P2	Computed as per Calendar Year:
	A3	Crop:
	B3	Rice
	F3	Table 11:
	I3	Table 12:
	J3	Following Adjustment:
	P3	J_{plant}
Table 2.5	Q3	=TRUNC(275*C5/9-30+C6)+IF(C5>2,-2,0)+IF(MOD(C15,4)=0,1,0)
	S3	field capacity=
	T3	0.2765
	V3	fw(irrig.):
	X3	1
	AE3	$Root_{min}$
	AF3	0.15
	AG3	M
	AH3	MAD Initial
	AK3	20
	AL3	%
	E4	L_{ini}
	F4	30
	H4	$K_{cb\ ini}$
	I4	1
	J4	=I4
	L4	$K_{c\ min}$
	M4	0.15 (K_{cmin} is normally equal to $K_{cb\ ini}$) *
	P4	J_{Dev}
	Q4	=Q3+F4
	S4	wilt point=
	T4	0.1827
	V4	REW:
	X4	=(3.121*X5+22.896)*T6
	Y4	Mm
	AE4	$Root_{max}$
	AF4	0.75
	AG4	M
	AH4	MAD After
	AK4	20
	AL4	%
	A5	Planting
	B5	Month

	C5	7
	E5	L_{dev}
	F5	30
	H5	$K_{cb\ mid}$
	I5	1.15
Equation 70	J5	=IF(I5<0.45,I5,I5+(0.04*($K$8-2)-0.004*($K$9-45))*(($M$5/3)^0.3))
	L5	Max. Ht. :
	M5	1
	N5	M
	P5	J_{mid}
	Q5	=Q4+F5
	S5	saturation=
	T5	0.321
	V5	TEW:
	X5	=1000*(T3-(0.5*T4))*T6
	Y5	mm
	AE5	Avail. Water
	AF5	=1000*(T3-T4)*1
	AG5	mm/m
	B6	Day
	C6	1
	E6	L_{mid}
	F6	40
	H6	$K_{cb\ end}$
	I6	0.6
Equation 70	J6	=IF(I6<0.45,I6,I6+(0.04*($K$8-2)-0.004*($K$9-45))*(($M$5/3)^0.3))
	P6	J_{late}
	Q6	=Q5+F6
	S6	Ze=
	T6	0.1
	V6	Initial De:
	X6	18.505
	Y6	Mm
	E7	L_{late}
	F7	30
	P7	$J_{harvest}$
	Q7	=Q6+F7
	V7	Initial fw:
	X7	1
	A8	Soil:
	B8	Sandy clay
	H8	Midseas.Av.Wind Speed:
	K8	=(VLOOKUP(Q6,D14:AP175,38)-VLOOKUP(Q5,D14:AP175,38))/(Q6-Q5)
	L8	m/sec
	M8	<-----Computed automatically from Lookup on column AO
	AH8	(Irrigation that is needed is presumed applied at beginning of next day)
	H9	Midseas.Av. RH_{min}:
	K9	=(VLOOKUP(Q6,D14:AP175,39)-VLOOKUP(Q5,D14:AP175,39))/(Q6-Q5)
	L9	%

	M9	<----Computed automatically from Lookup on Column AP
	A14	6
	B14	1
	C14	2009
Table 2.5	D14	=TRUNC(275*A14/9-30+B14)+IF(A14>2,-2,0)+IF(MOD(C14,4)=0,1,0)
	E14	38
	F14	3.3324
	G14	--
	H14	7.90
Equation 14	I14	--
Equation 11	J14	--
	K14	48
	L14	0
	M14	--
	N14	--
	O14	=IF(D14<$Q$4,$J$4,IF(D14<$Q$5,$J$4+(D14-$Q$4)/$F$5*($J$5-$J$4),IF(D14<$Q$6,$J$5,IF(D14<$Q$7,$J$5+(D14-$Q$6)/$F$7*($J$6-$J$5),$J$4))))
	P14	=MAX(O14/$J$5*$M$5,P13)
Equation 72	Q14	=MAX(1.2+(0.04*(F14*0.9-2)-0.004*(K14-45))*(P14/3)^0.3,O14+0.05)
	R14	0
Equation 76	S14	=MAX(((O14-M$4)/(Q14-M$4))^(1+(0.5*P14)),0.01)
	T14	=IF(R14>0,X$3,IF(L14>0,1,X7))
Equation 75	U14	=MIN(1-S14,T14)
	V14	=X6
Equation 74	W14	=MAX(IF(V14<X$4,1,(X$5-V14)/(X$5-X$4)),0)
Equation 71	X14	=MIN(+W14*(Q14-O14),U14*Q14)
	Y14	=X14*H14
Equation 79	Z14	=MAX(L14+R14,0)
Equation 77	AA14	=V14-L14-R14+(Y14/U14)+Z14
	AB14	=O14+X14
Equation 69	AC14	=AB14*H14
Equation 8.1	AE14	=MAX((O14-$J$4)/($J$5-$J$4)*($AF$4-$AF$3)+$AF$3,AE13)
Equation 82	AF14	=MAX(IF(D14<Q$4,AK$3,AK$4)/100*AE14*$AF$5,AF13)
Equation 85	AG14	=MAX($X$6-L14+AC14,0)
	AH14	0
Equation 88	AI14	=MAX(+L14-AC14-$X$6,0)
Equation 84	AJ14	=MAX(IF(AG14<AF14,1,(AE14*AF$5-AG14)/(AE14*AF$5-AF14)),0)
Equation 80	AK14	=X14+O14*AJ14
Equation 85	AL14	=+$X$6-L14+(AK14*H14)+AI14
	AM14	=AK14*H14
	AO14	=F14
	AP14	=K14
	AR14	0
	AT14	0
	AU14	=AM14-AT14
	AV14	=IF(AL14-$X$6>0, AL14-$X$6,0)
	AW14	=IF(AL14-$X$6<0, AL14-$X$6,0)
	AX14	=AR14
	AY14	=R14
	AZ14	=AM14
	BA14	=1000*($T$5-$T$3)*AE14
	BB14	=IF(AI14<=BA14,0,(AL14-X6+AX14+AY14-AZ14-BA14))
	BC14	=IF(AI14<BA14,AI14,BA14)
	BD14	=AV14+AW14+AX14+AY14-AZ14-BB14-BC14

Second Row of Formulas and All rows below row 15 are similar		
	A15	6
	B15	2
	C15	2009
	D15	=TRUNC(275*A15/9-30+B15)+IF(A15>2,-2,0)+IF(MOD(C15,4)=0,1,0)
	E15	38
	F15	4.4432
	G15	--
	H15	8.70
Equation 14	I15	--
Equation 11	J15	--
	K15	48
	L15	0
	M15	--
	N15	--
Equation 66	O15	=IF(D15<$Q$4,$J$4,IF(D15<$Q$5,$J$4+(D15-$Q$4)/$F$5*($J$5-$J$4),IF(D15<$Q$6,$J$5,IF(D15<$Q$7,$J$5+(D15-$Q$6)/$F$7*($J$6-$J$5),$J$4))))
	P15	=MAX(O15/$J$5*$M$5,P14)
Equation 72	Q15	=MAX(1.2+(0.04*(F15*0.9-2)-0.004*(K15-45))*(P15/3)^0.3,O15+0.05)
	R15	=AH14
Equation 76	S15	=MAX(((O15-M$4)/(Q15-M$4))^(1+0.5*P15),0.01)
	T15	=IF(R15>0,X$3,IF(L15>0,1,T14))
Equation 75	U15	=MIN(1-S15,T15)
	V15	=MAX(AA14-L15-R15,0)
Equation 74	W15	=MAX(IF(V15<X$4,1,(X$5-V15)/(X$5-X$4)),0)
Equation 71	X15	=MIN(+W15*(Q15-O15),U15*Q15)
	Y15	=X15*H15
Equation 79	Z15	=MAX(L15+R15-AA14,0)
Equation 77	AA15	=AA14-L15-R15+(Y15/U15)+Z15
	AB15	=O15+X15
Equation 69	AC15	=AB15*H15
Equation 8.1	AE15	=MAX((O15-$J$4)/($J$5-$J$4)*($AF$4-$AF$3)+$AF$3,AE14)
Equation 82	AF15	=MAX(IF(D15<Q$4,AK$3,AK$4)/100*AE15*$AF$5,AF14)
Equation 85	AG15	=MAX(AL14-L15-AH14+AC15,0)
	AH15	0
	AI15	=MAX(+L15+AH14-AC15-AL14,0)
	AJ15	=MAX(IF(AG15<AF15,1,(AE15*AF$5-AG15)/(AE15*AF$5-AF15)),0)
Equation 80	AK15	=(AJ15*O15)+X15
	AL15	=+AL14-L15-AH14+(AK15*H15)+AI15
	AM15	=AK15*H15
	AO15	=+AO14+F15
	AP15	=AP14+K15
	AR15	0
	AT15	0
	AU15	=AM15-AT15
	AV15	=IF(AL15-AL14>0, AL15-AL14,0)
	AW15	=IF(AL15-AL14<0, AL15-AL14,0)
	AX15	=AR15
	AY15	=R15
	AZ15	=AM15
	BA15	=1000*($T$5-$T$3)*AE15
	BB15	=IF(AI15<=BA15,0,(AL15-AL14+AX15+AY15-AZ15-BA15))
	BC15	=IF(AI15<BA15,AI15,BA15)
	BD15	=AV15+AW15+AX15+AY15-AZ15-BB15-BC15

SPREADSHEET 2:

Spreadsheet for calculating Actual ET and Irrigation Scheduling from A to L column for rows 1 to 50

	A	B	C	D	E	F	G	H	I	J	K	L
1	EXAMPLE SPREADSHEET FOR CALCULATING ACTUAL EVAPOTRANSPIRATION (ET act) AND AN IRRIGATION SCHEDULE											
2	Block 1											
3	Crop:	Rice				Table 11:			Table 12:	Following Adjustment:		
4					Lini	30		Kcb ini	1	1.00		Kc min
5	Planting:	Month	7		Ldev	30		Kcb mid	1.15	1.04		Max. Ht. :
6		Day	1		Lmid	40		Kcb end	0.6	0.49		
7					Llate	30						
8	Soil :	Sandy clay						Midseas.Av.Wind Speed:			1.17	m/sec
9								Midseas.Av. RHmin:			76.13	%
10												
11						WIND						
12					Tmax	AT 2 m	Tdew	Eto	e0(Tdew)	e0(Tmax)	RHmin	P-RO
13	MONTH	DAY	YEAR	J	C	m/s	C	mm/day	kPa	kPa	%	mm
14	6	1	2009	152	38	3.33		7.90			48	0.00
15	6	2	2009	153	38	4.44		8.70			48	0.00
16	6	3	2009	154	38	2.22		7.34			48	0.00
17	6	4	2009	155	38	2.22		7.21			53	0.00
18	6	5	2009	156	38	2.78		7.72			48	0.00
19	6	6	2009	157	39	2.22		7.12			50	0.00
20	6	7	2009	158	39	2.78		7.62			50	0.00
21	6	8	2009	159	38	2.22		7.01			53	0.00
22	6	9	2009	160	39	3.33		7.93			50	0.00
23	6	10	2009	161	39	3.33		8.04			50	0.00
24	6	11	2009	162	39	1.67		6.36			48	0.00
25	6	12	2009	163	39	2.78		7.52			50	0.00
26	6	13	2009	164	39	2.22		7.07			50	0.00
27	6	14	2009	165	38	2.22		7.03			48	0.00
28	6	15	2009	166	38	3.89		7.92			53	0.00
29	6	16	2009	167	39	3.33		7.83			50	0.00
30	6	17	2009	168	39	2.22		7.29			45	0.00
31	6	18	2009	169	40	2.22		7.29			45	0.00
32	6	19	2009	170	40	2.22		7.31			45	0.00
33	6	20	2009	171	39	2.22		6.25			50	0.00
34	6	21	2009	172	38	1.11		3.96			53	0.00
35	6	22	2009	173	38	1.67		5.95			53	0.00
36	6	23	2009	174	37	2.78		7.47			35	0.00
37	6	24	2009	175	36	1.11		5.81			58	21.00
38	6	25	2009	176	37	1.11		5.89			58	0.00
39	6	26	2009	177	39	1.67		5.56			53	0.00
40	6	27	2009	178	37	2.22		6.63			53	0.00
41	6	28	2009	179	38	1.67		5.41			49	0.00
42	6	29	2009	180	34	1.67		3.74			62	3.00
43	6	30	2009	181	36	2.78		6.27			62	0.00
44	7	1	2009	182	38	1.67		5.72			53	0.00
45	7	2	2009	183	36	1.67		5.29			56	0.00
46	7	3	2009	184	34	1.11		4.11			62	4.00
47	7	4	2009	185	38	1.11		4.47			67	0.00
48	7	5	2009	186	35	1.11		4.70			68	2.00
49	7	6	2009	187	36	1.11		5.31			62	20.00
50	7	7	2009	188	35	1.11		4.87			68	5.50

Continued Spreadsheet for calculating Actual ET and Irrigation Scheduling from M to Y column for rows 1 to 50

	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1				Computed Dates for stages:									
2				Computed Dates for stages:	As per calender year								
3				Jplant	182		field capacity=	0.28		fw(irrig.):		1	
4	0.15			JDev	212		wilt point=	0.18		REW:		8.07	mm
5	1	m		Jmid	242		saturation=	0.32		TEW:		18.51	mm
6				Jlate	282		Ze=	0.10		Initial De:		18.51	
7				Jharvest	312					Initial fw:		1	
8	<-----Computed automatically from Lookup on column AO												
9	<----Computed automatically from Lookup on Column AP												
10													
11						NET Irr./fw				De,i			
12				Ht		(Beg. Of day)				START			E (Ei-WEAP)
13			Kcb	m	Kcmax	mm	fc	fw	few	mm	Kr	Ke	mm/day
14			1	0.96	1.22	0	0.71	1	0.29	18.51	0	0	0.00
15			1	0.96	1.25	0	0.68	1	0.32	18.51	0	0	0.00
16			1	0.96	1.19	0	0.74	1	0.26	18.51	0	0	0.00
17			1	0.96	1.18	0	0.76	1	0.24	18.51	0	0	0.00
18			1	0.96	1.21	0	0.73	1	0.27	18.51	0	0	0.00
19			1	0.96	1.19	0	0.75	1	0.25	18.51	0	0	0.00
20			1	0.96	1.20	0	0.73	1	0.27	18.51	0	0	0.00
21			1	0.96	1.18	0	0.76	1	0.24	18.51	0	0	0.00
22			1	0.96	1.21	0	0.72	1	0.28	18.51	0	0	0.00
23			1	0.96	1.21	0	0.72	1	0.28	18.51	0	0	0.00
24			1	0.96	1.18	0	0.76	1	0.24	18.51	0	0	0.00
25			1	0.96	1.20	0	0.73	1	0.27	18.51	0	0	0.00
26			1	0.96	1.19	0	0.75	1	0.25	18.51	0	0	0.00
27			1	0.96	1.19	0	0.74	1	0.26	18.51	0	0	0.00
28			1	0.96	1.22	0	0.71	1	0.29	18.51	0	0	0.00
29			1	0.96	1.21	0	0.72	1	0.28	18.51	0	0	0.00
30			1	0.96	1.20	0	0.73	1	0.27	18.51	0	0	0.00
31			1	0.96	1.20	0	0.73	1	0.27	18.51	0	0	0.00
32			1	0.96	1.20	0	0.73	1	0.27	18.51	0	0	0.00
33			1	0.96	1.19	0	0.75	1	0.25	18.51	0	0	0.00
34			1	0.96	1.15	0	0.79	1	0.21	18.51	0	0	0.00
35			1	0.96	1.16	0	0.77	1	0.23	18.51	0	0	0.00
36			1	0.96	1.24	0	0.69	1	0.31	18.51	0	0	0.00
37			1	0.96	1.13	0	0.80	1	0.20	0.00	1	0.13	0.78
38			1	0.96	1.13	0	0.80	1	0.20	3.99	1	0.13	0.79
39			1	0.96	1.16	0	0.77	1	0.23	8.04	1	0.16	0.91
40			1	0.96	1.18	0	0.76	1	0.24	12.00	0.6	0.11	0.73
41			1	0.96	1.17	0	0.76	1	0.24	14.99	0.3	0.06	0.32
42			1	0.96	1.14	0	0.80	1	0.20	13.31	0.5	0.07	0.26
43			1	0.96	1.17	0	0.77	1	0.23	14.59	0.4	0.06	0.39
44			1.00	0.96	1.16	200	0.77	1	0.23	0.00	1.00	0.16	0.93
45			1.00	0.96	1.15	0	0.78	1	0.22	4.07	1.00	0.15	0.82
46			1.00	0.96	1.12	0	0.82	1	0.18	3.80	1.00	0.12	0.51
47			1.00	0.96	1.11	0	0.84	1	0.16	6.58	1.00	0.11	0.49
48			1.00	0.96	1.11	0	0.84	1	0.16	7.56	1.00	0.11	0.50
49			1.00	0.96	1.12	0	0.82	1	0.18	0.00	1.00	0.12	0.65
50			1.00	0.96	1.11	0	0.84	1	0.16	0.00	1.00	0.11	0.52

Continued Spreadsheet for calculating Actual ET and Irrigation Scheduling from Z to AJ column for rows 1 to 50

	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ
1											
2											
3						Rootmin	0.15	m	MAD Initial		
4						Rootmax	0.75	m	MAD After		
5						Avail. Water	93.7	mm/m			
6											
7											
8											
9									From Preci.		
10											
11		De,i				ROOT		ENDING	NET	DRAINAGE	Ks
12	DPe	END				DEPTH m	RAW	DEPL.(Dr,i)	IRRI.NEEDED	(DP)	
13	mm/day	mm	Kc	ETc		Annex 8 Eqn 8.1	mm	mm	0	mm	
14	0	18.51	1	7.90		0.15	2.81	26.40	0.00	0.00	0.00
15	0	18.51	1	8.70		0.15	2.81	27.20	0.00	0.00	0.00
16	0	18.51	1	7.34		0.15	2.81	25.85	0.00	0.00	0.00
17	0	18.51	1	7.21		0.15	2.81	25.71	0.00	0.00	0.00
18	0	18.51	1	7.72		0.15	2.81	26.23	0.00	0.00	0.00
19	0	18.51	1	7.12		0.15	2.81	25.63	0.00	0.00	0.00
20	0	18.51	1	7.62		0.15	2.81	26.12	0.00	0.00	0.00
21	0	18.51	1	7.01		0.15	2.81	25.52	0.00	0.00	0.00
22	0	18.51	1	7.93		0.15	2.81	26.44	0.00	0.00	0.00
23	0	18.51	1	8.04		0.15	2.81	26.54	0.00	0.00	0.00
24	0	18.51	1	6.36		0.15	2.81	24.86	0.00	0.00	0.00
25	0	18.51	1	7.52		0.15	2.81	26.03	0.00	0.00	0.00
26	0	18.51	1	7.07		0.15	2.81	25.58	0.00	0.00	0.00
27	0	18.51	1	7.03		0.15	2.81	25.54	0.00	0.00	0.00
28	0	18.51	1	7.92		0.15	2.81	26.43	0.00	0.00	0.00
29	0	18.51	1	7.83		0.15	2.81	26.33	0.00	0.00	0.00
30	0	18.51	1	7.29		0.15	2.81	25.80	0.00	0.00	0.00
31	0	18.51	1	7.29		0.15	2.81	25.79	0.00	0.00	0.00
32	0	18.51	1	7.31		0.15	2.81	25.81	0.00	0.00	0.00
33	0	18.51	1	6.25		0.15	2.81	24.75	0.00	0.00	0.00
34	0	18.51	1	3.96		0.15	2.81	22.46	0.00	0.00	0.00
35	0	18.51	1	5.95		0.15	2.81	24.45	0.00	0.00	0.00
36	0	18.51	1	7.47		0.15	2.81	25.98	0.00	0.00	0.00
37	2.495	3.99	1.1	6.59		0.15	2.81	4.09	0.00	0.00	0.89
38	0	8.04	1.1	6.68		0.15	2.81	10.12	0.00	0.00	0.35
39	0	12.00	1.2	6.46		0.15	2.81	12.75	0.00	0.00	0.12
40	0	14.99	1.1	7.37		0.15	2.81	15.21	0.00	0.00	0.00
41	0	16.31	1.1	5.73		0.15	2.81	14.30	0.00	0.00	0.00
42	0	14.59	1.1	4.00		0.15	2.81	9.88	0.00	0.00	0.37
43	0	16.27	1.1	6.66		0.15	2.81	14.19	200.00	0.00	0.00
44	183.73	4.07	1.16	6.65		0.15	2.81	0.00	0.00	185.42	1.00
45	0.00	7.80	1.15	6.11		0.15	2.81	6.11	0.00	0.00	0.71
46	0.00	6.58	1.12	4.61		0.15	2.81	5.17	0.00	0.00	0.79
47	0.00	9.56	1.11	4.96		0.15	2.81	9.27	0.00	0.00	0.43
48	0.00	10.68	1.11	5.20		0.15	2.81	9.90	0.00	0.00	0.37
49	9.32	3.60	1.12	5.97		0.15	2.81	0.00	0.00	7.10	1.00
50	1.90	3.23	1.11	5.39		0.15	2.81	0.00	0.00	0.11	1.00

Continued Spreadsheet for calculating Actual ET and Irrigation Scheduling from AK to AU column for rows 1 to 50

	AK	AL	AM	AN	AO	AP	AQ	AR	AS	AT	AU
1											
2											
3	20	%									
4	20	%									
5											
6											
7											
8											
9											
10											
11	ADJUSTED Kc	CORRECT	CORRECTED		CUMULATIVE						Diff of
12	Ks*Kcb+Ke	Ending DEPL.	ETc		WIND SPEED	MIN. HUMIDITY		Rainfall		WEAP ETa	WEAP & Calculated
13	(Kc adj.)	mm	mm		m/s	%		mm		mm	Mm
14	0.00	18.51	0.00		3.33	48		0.00		0.00	0.00
15	0.00	18.51	0.00		7.78	96		0.00		0.00	0.00
16	0.00	18.51	0.00		10.00	144		0.00		0.00	0.00
17	0.00	18.51	0.00		12.22	197		0.00		0.00	0.00
18	0.00	18.51	0.00		15.00	245		0.00		0.00	0.00
19	0.00	18.51	0.00		17.22	295		0.00		0.00	0.00
20	0.00	18.51	0.00		19.99	345		0.00		0.00	0.00
21	0.00	18.51	0.00		22.22	398		0.00		0.00	0.00
22	0.00	18.51	0.00		25.55	448		0.00		0.00	0.00
23	0.00	18.51	0.00		28.88	498		0.00		0.00	0.00
24	0.00	18.51	0.00		30.55	546		0.00		0.00	0.00
25	0.00	18.51	0.00		33.32	596		0.00		0.00	0.00
26	0.00	18.51	0.00		35.55	646		0.00		0.00	0.00
27	0.00	18.51	0.00		37.77	694		0.00		0.00	0.00
28	0.00	18.51	0.00		41.66	747		0.00		0.00	0.00
29	0.00	18.51	0.00		44.99	797		30.70		0.00	0.00
30	0.00	18.51	0.00		47.21	842		10.00		0.00	0.00
31	0.00	18.51	0.00		49.43	887		4.00		0.00	0.00
32	0.00	18.51	0.00		51.65	932		9.56		0.00	0.00
33	0.00	18.51	0.00		53.87	982		16.28		0.00	0.00
34	0.00	18.51	0.00		54.98	1035		19.16		0.00	0.00
35	0.00	18.51	0.00		56.65	1088		24.80		0.00	0.00
36	0.00	18.51	0.00		59.43	1123		17.13		0.00	0.00
37	1.02	3.43	5.93		60.54	1181		15.27		6.69	-0.77
38	0.48	6.29	2.86		61.65	1239		1.00		6.79	-3.93
39	0.28	7.84	1.55		63.32	1292		0.00		5.36	-3.81
40	0.11	8.57	0.73		65.54	1345		2.00		3.29	-2.55
41	0.06	8.89	0.32		67.20	1394		0.00		1.33	-1.01
42	0.44	7.53	1.64		68.87	1456		19.89		1.55	0.09
43	0.06	7.92	0.39		71.65	1518		1.00		3.04	-2.65
44	1.16	0.00	6.65		73.31	1571		0.00		5.98	0.67
45	0.86	4.56	4.56		74.98	1627		0.00		5.69	-1.14
46	0.91	4.31	3.75		76.09	1689		17.51		4.14	-0.39
47	0.53	6.70	2.39		77.20	1756		10.14		3.04	-0.65
48	0.48	6.94	2.24		78.31	1824		1.00		2.80	-0.56
49	1.12	0.00	5.97		79.42	1886		0.00		6.00	-0.03
50	1.11	0.00	5.39		80.53	1954		0.00		5.41	-0.03

Continued Spreadsheet for calculating Actual ET and Irrigation Scheduling from AV to BD column for rows 1 to 50

Water Balance

	AV	AW	AX	AY	AZ	BA	BB	BC	BD
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12	Decrease soil moisture	Increase soil moisture	Precipitation	Irrigation	Actual ETa	DPmax	Surface Runoff	Flow to Ground Water	**Sum**
13	mm	mm	mm	mm	mm	mm	mm	mm	
14	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
22	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
23	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
25	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
26	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
29	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
30	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
31	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
32	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
33	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
34	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
35	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
36	0.00	0.00	0.00	0.00	0.00	6.69	0.00	0.00	0.00
37	0.00	-15.07	21.00	0.00	5.93	6.69	0.00	0.00	0.00
38	2.86	0.00	0.00	0.00	2.86	6.69	0.00	0.00	0.00
39	1.55	0.00	0.00	0.00	1.55	6.69	0.00	0.00	0.00
40	0.73	0.00	0.00	0.00	0.73	6.69	0.00	0.00	0.00
41	0.32	0.00	0.00	0.00	0.32	6.69	0.00	0.00	0.00
42	0.00	-1.36	3.00	0.00	1.64	6.69	0.00	0.00	0.00
43	0.39	0.00	0.00	0.00	0.39	6.69	0.00	0.00	0.00
44	0.00	-7.92	0.00	200.00	6.65	6.69	178.73	6.69	0.00
45	4.56	0.00	0.00	0.00	4.56	6.69	0.00	0.00	0.00
46	0.00	-0.25	4.00	0.00	3.75	6.69	0.00	0.00	0.00
47	2.39	0.00	0.00	0.00	2.39	6.69	0.00	0.00	0.00
48	0.24	0.00	2.00	0.00	2.24	6.69	0.00	0.00	0.00
49	0.00	-6.94	20.00	0.00	5.97	6.69	0.41	6.69	0.00
50	0.00	0.00	5.50	0.00	5.39	6.69	0.00	0.11	0.00

Appendix V

Ph.D. course work certificate

सत्यं शिवं सुन्दरम्

THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA

CERTIFICATE

[As per O.Ph.D. 2 under UGC (Minimum Standards and Procedure for Awards of M.Phil./Ph.D. Degree) Regulation, 2009 for 15 Credits to be earned by Ph.D. Scholars]

This is to certify that **Mr. Bhatti Gopal Hiraji,** Research Scholar, registered under UGC (*Minimum Standards and Procedure for Awards of M.Phil./Ph.D. Degree) Regulation, 2009,* vide Registration Certificate Number 264 dated 16/05/2012, for pursuing Ph.D. on has undertaken and completed the course work with the Grade A.

STATEMENT OF CREDITS EARNED

Name of Research Scholar: **Mr. Bhatti Gopal Hiraji** *(M)*

Faculty/Institution: Faculty of Technology

Department: Department of Civil

Paper Number	Course Title	Course Credits	Grade Earned
Core Courses – 09 Credits *[Offered At University Level]*			
I.	Introduction to Research & Research Writings	3	B
II.	Introduction to Basic Computer Functions & Application for Research Purposes	3	B
III.	Quantitative Research Techniques & Data Analysis	3	B
Departmental Courses – 06 Credits *[Offered at Departmental Level]*			
IV.	Advanced Studies in Irrigation Engineering	4	A
V.	Seminar: Deficit Irrigation using WEAP Model	2	A
		Overall Grade	**A**

ACA1//2

Date of Issue: 02/04/2013

Place: Vadodara

Registrar (OSD)

Grade Conversion Table and Grade Calculation Formula

Grade	Grade Points	Range
O	10	Above 9.01
A	9	8.01 – 9.00
B	8	7.01 – 8.00
C	7	6.01 – 7.00
D	6	5.01 – 6.00
E	5	4.01 – 5.00
F	4	Below 4.00

$$Overall\ Grade = \frac{\sum(Grade\ Points \times Credits)}{\sum Credits}$$

Appendix VI

Research Contributions

1) "Estimation of evapotranspiration in Sardar Sarovar command area using WEAP" **2012 International SWAT Conference & Workshops** Organized by Texas Agri Life Research and Indian Institute of Technology, Delhi, 18-20 July 2012.

2) "Estimation of Evapotranspiration for Four Major Crops using Dual Crop Coefficient Method in Sardar Sarovar Command Area" **National Conference HYDRO-2012, IIT Bombay, Mumbai** Organized by Department of Civil Engineering, IIT Bombay, Mumbai and Indian Society for Hydraulics, Pune, 7 & 8th December 2012.

3) **"**Methods for estimation of crop evapotranspiration using crop coefficient and other approaches: Review" **International symposium on "New-Dimensions in Agrometeorology for Sustainable Agriculture (NASA-2014)"**, G. B. Pant University of Agriculture & Technology, Pantnagar, India, 16-18 October, 2014.

4) "Estimating Reference Evapotranspiration for Agro-Climatic Region-1 of Sardar Sarovar Command" **International symposium on "New-Dimensions in Agrometeorology for Sustainable Agriculture (NASA-2014)"**, G. B. Pant University of Agriculture & Technology, Pantnagar, India, 16-18 October, 2014.

5) **"**Methods for Estimation of Crop Evapotranspiration Using Climate Data: A Review" **International Journal of Engineering Research ISSN: 2319-6890 (online), 2347-5013(print) Issue Special3 18-19, Dec. 2014. Paper published**.

6) "Irrigation scheduling strategies for cotton crop in semi-arid climate using WEAP model." **Journal of Indian Water Resources Society, Vol-35, No1 Jan-2015 p.p. 7-15**, ISSN 0970-6984, **Paper published.**

7) “Evaluating Irrigation Strategies for Rice Using WEAP-MABIA Model: A Case Study in Region-I of Sardar Sarovar Command Area, India” **INTERNATIONAL SWAT-ASIA CONFERENCE IV , TSUKUBA, JAPAN,** Organized by , Monsoon Asia Agro-Environmental Research Consortium(MARCO), National Institute for Agro-Environmental Sciences (NIAES)**,** Japan International Research Centre for Agricultural Sciences(JIRCAS)**,** Tsukuba Bioscience Hall, Tsukuba, Ibaraki, JAPAN**,** October 20-23,2015.

8) “Simulation of soil moisture balance with conjunctive use of groundwater and canal water irrigation: A case study for castor crop in Region-I of Sardar Sarovar Command Area.” **INTERNATIONAL SWAT-ASIA CONFERENCE IV, TSUKUBA, JAPAN,** Organized by , Monsoon Asia Agro-Environmental Research Consortium(MARCO), National Institute for Agro- Environmental Sciences (NIAES)**,** Japan International Research Centre for Agricultural Sciences(JIRCAS)**,** Tsukuba Bioscience Hall, Tsukuba, Ibaraki, JAPAN**,** October 20-23,2015.