ESTIMATION OF EVAPOTRANSPIRATION IN SARDAR SAROVAR COMMAND AREA USING WEAP

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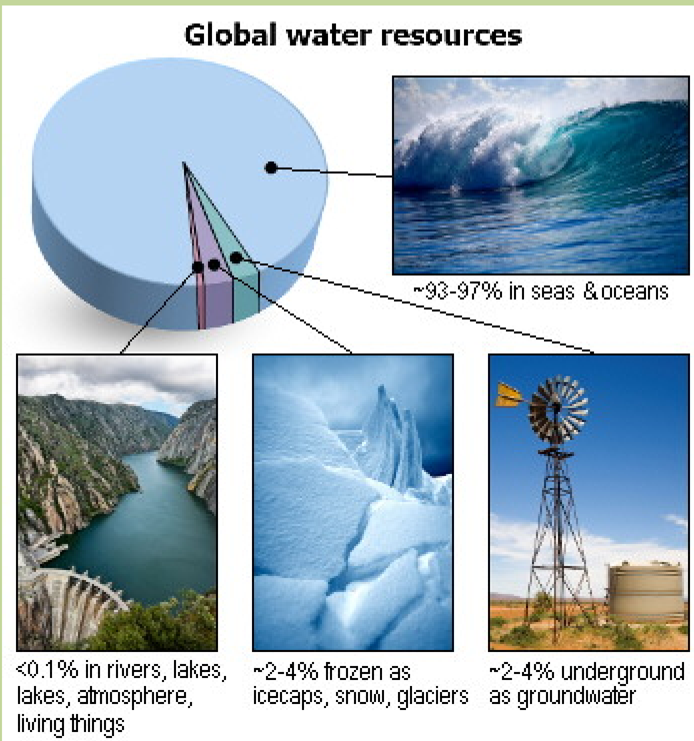
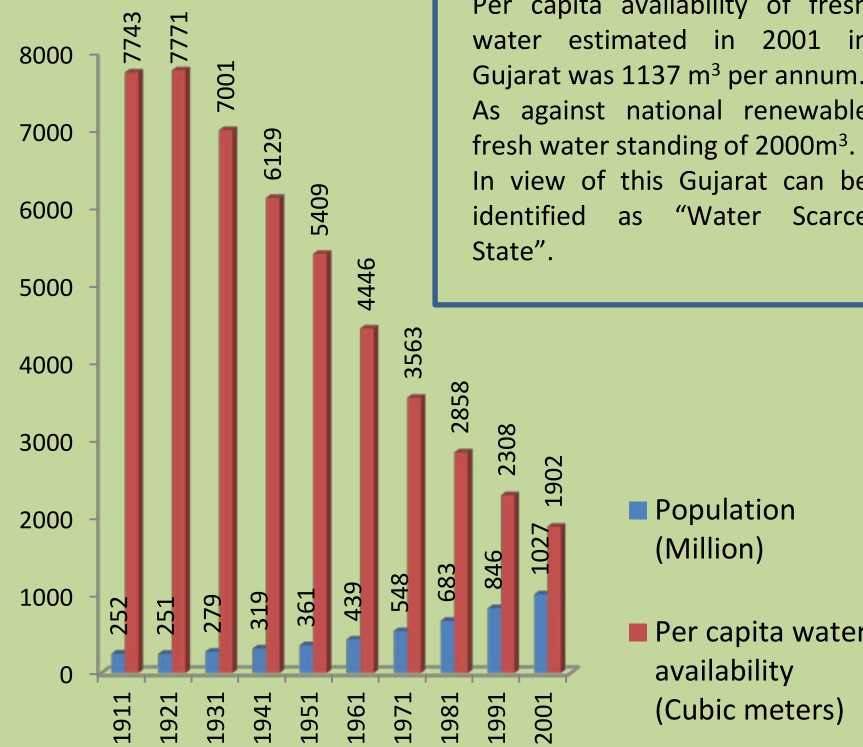
India's Population and Per-capita Water Availability



Per capita availability of fresh water estimated in 2001 in Gujarat was 1137 m^3 per annum. As against national renewable fresh water standing of $2000m^3$. In view of this Gujarat can be identified as "Water Scarce State".



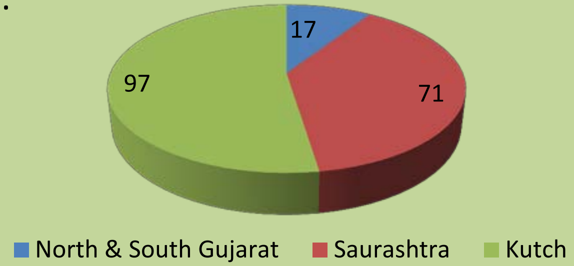
Source : Tata Energy Research Institute, (TERI), 1998 and Census India, 2001.

Available Water Resources in Gujarat State

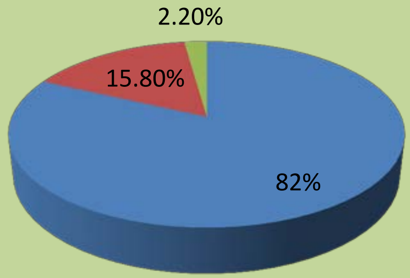
- Total geographical area of state is 19.6 M ha.
- Cultivable area is 12.5 M ha.
- Population of about 60.38 million (as per 2011 census).
- States decade growth rate 19.17 %.
- The state's water resources are just 2.28% of India's total water resources.
- Indicating the low availability per-capita water.
- Source : Gujarat State Water Policy, 2004 & GWSSB, 2005

River basins in Gujarat State

Total 185 river basins in the state of Gujarat
17 basins are in the North and South Gujarat;
71 and 97 basins are in Saurashtra and Kutch region.



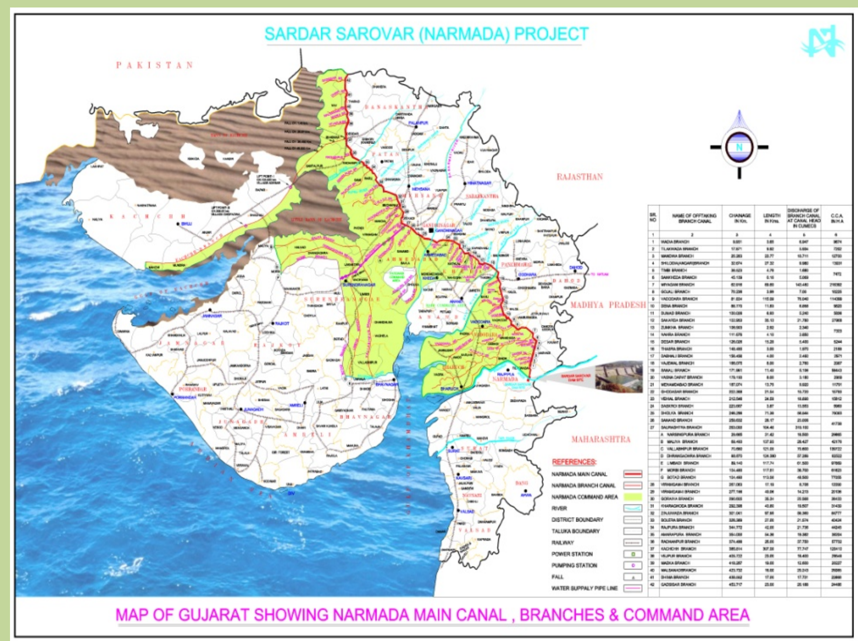
Availability of quantum of water resources in Gujarat State



The availability of quantum of water resources in the north and south Gujarat is 82% .
Total water available in Saurashtra and Kutch region is 15.80% and 2.20% respectively.

Sardar Sarovar Project Command Area

- The Sardar Sarovar Project is one of the largest irrigation projects of India.
- The GCA is 3.43 M ha, while CCA is 2.12 M ha.
- Around 8215 villages and 135 towns/cities of Gujarat shall be covered under Narmada Project.
- Soil distribution ranges from loamy to clayey.
- Crops grown in the area are maize, cotton, pulses, paddy, bajra, castor, tobacco and pulses in Kharif and wheat, maize, gram, jowar, pulses, vegetables in Rabi season



Objectives

- To estimate the actual crop evapotranspiration of maize and wheat crops in the study area.
- To carry out daily soil moisture balance in root zone.
- To evaluate two different irrigation scheduling strategies, conventional and model based.

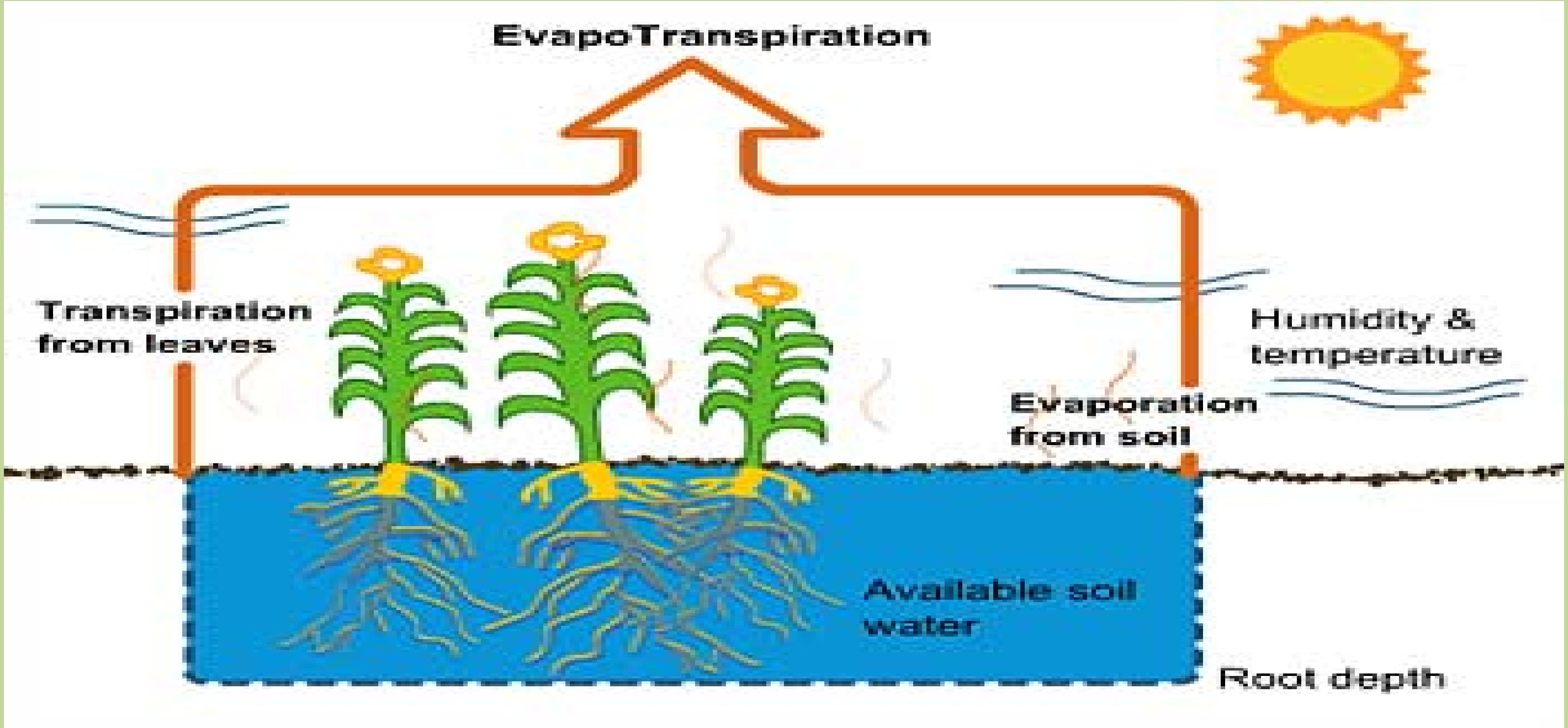
Methodology

- Data collection related to irrigation and crop water requirements from various agencies**.**
- Estimation of Reference evapotranspiration by using daily meteorological data of the year 2008-09 .
- Computing crop evapotranspiration for selected major crops.
- Estimating irrigation requirements.
- Working out strategies for irrigation.
- Software usage

- **Using MABIA Method in WEAP**

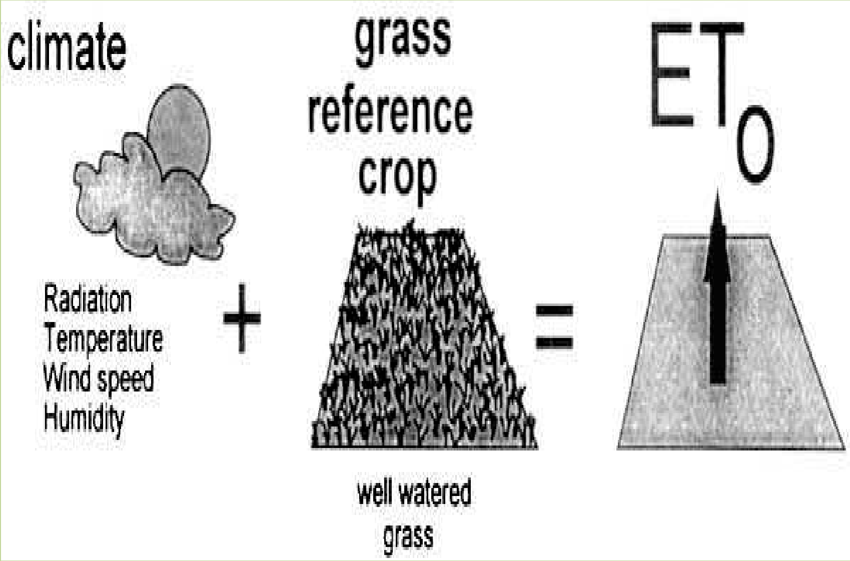
  It includes modules for estimating reference evapotranspiration and soil water capacity. For a daily simulation of transpiration, evaporation, irrigation requirements and scheduling
- The method uses dual crop coefficient where crop coefficient value is divided into a 'basal' crop coefficient, k_{cb} and a separate, K_e, representing evaporation from the soil surface.
- The method is an improvement over CROPWAT, which uses single crop coefficient and hence, does not separate evaporation and transpiration.

CROP WATER REQUIREMENT



- **Crop water requirement = Evaporation +Transpiration +Seepage below the Ground + Drainage.**
- **Major component is evaporation and transpiration combined to gather named Evapotranspiration.**

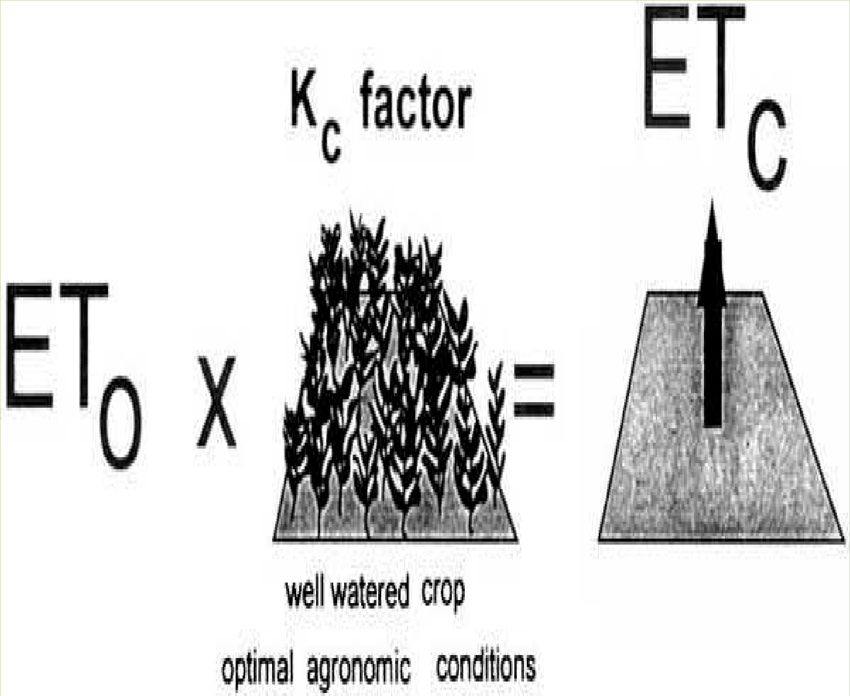
Reference ETo



- The rate of evapotranspiration from a reference surface is called reference evapotranspiration.
- ETo can be computed from meteorological data and crop data. It depends on:
- Weather parameters such as radiation, maximum and minimum temperature, humidity and wind speed;
- Crop factors such as crop type, development stage, crop height, type of irrigation and Management and environmental conditions
- Different climatological methods are used for estimating reference crop evapotranspiration (ETo).
- The FAO Penman-Monteith method is recommended as the sole standard method for the definition and computation of the ETo.

$$ETo = \frac{0.408\,\Delta(Rn - G) + \gamma\frac{900}{T + 273}U_2(es - ea)}{\Delta + \gamma(1 + 0.34U_2)}$$

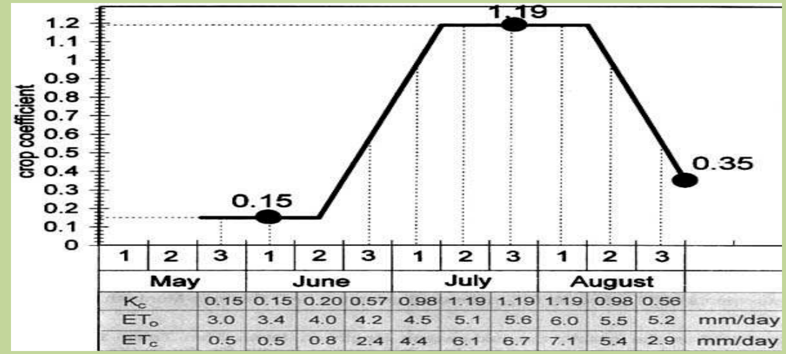
Potential Evapotranspiration under Standard conditions (ETc)

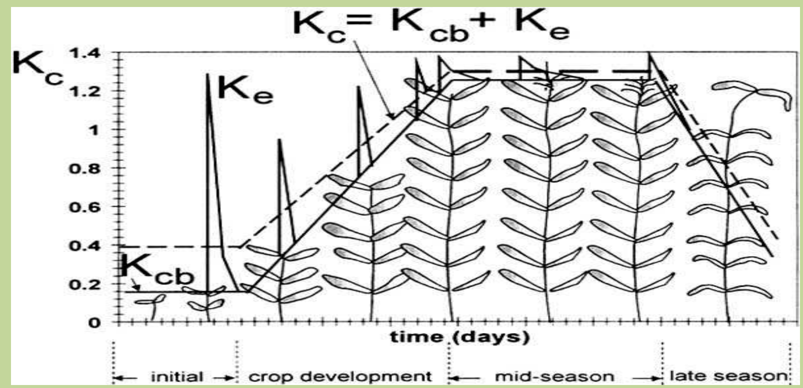


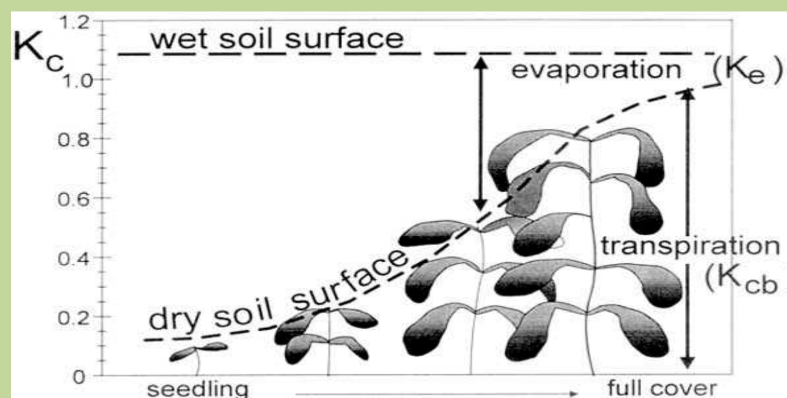
- Amount of water that would be consumed by evapotranspiration if no water restrictions exists.
- The soil has extensive moisture and it is covered by fully developed vegetation.
- Crop evapotranspiration (ETc) can be calculated by multiplying the reference ETo by crop coefficient Kc (Allen et al., 1998).

Crop Coefficient

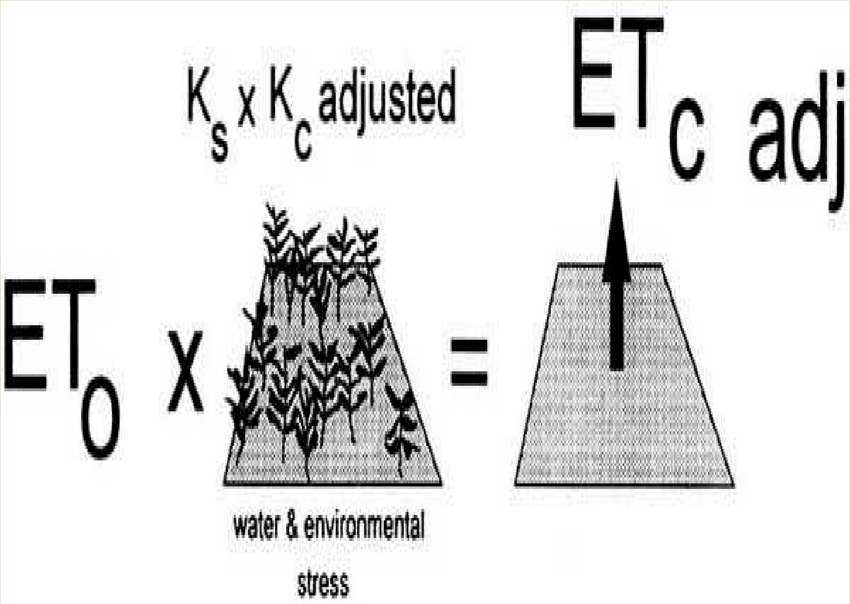
- Crop coefficient (Kc) can be calculated by two approaches.
- Single crop coefficient and dual crop coefficient.
- In single crop coefficient, difference in Evaporation and transpiration between field crops and reference grass surface can be integrated in a single crop coefficient (Kc).
- Dual crop coefficient is separated into two coefficients :–
- A basal crop coefficient (Kcb). Actual evapotranspiration conditions when the soil surface is dry but sufficient root zone moisture is present to support full transpiration.
- A soil evaporation coefficient (Ke). Soil evaporation coefficient (Ke) calculated when the topsoil dries out, and evaporation is less and evaporation reduces in proportion to the amount of water available in surface soil layer .
- Source : (Allen et al., 1998; Allen R. G. 2002; Allen et al., 2005







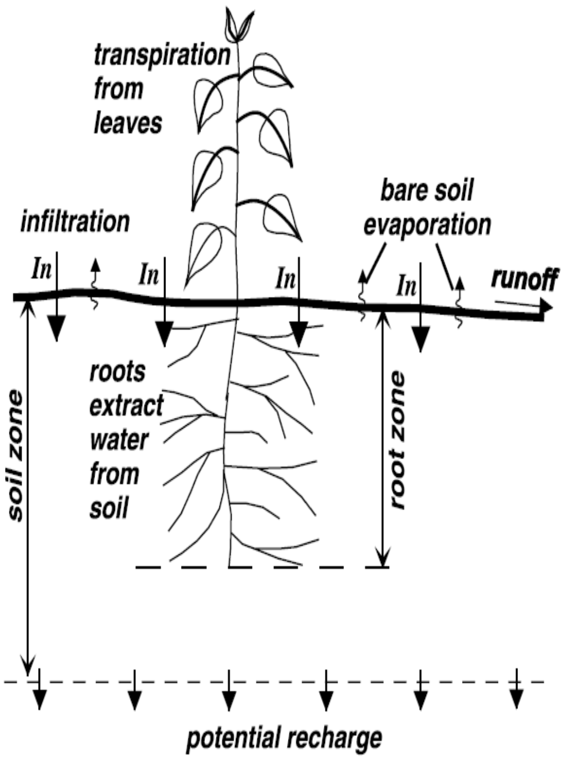
Actual Evapotranspiration under non standard conditions (ETc act)



- It is the amount of water that would be consumed by evapotranspiration in the catchment, including water supplied by irrigation also. It is also known as ET adj.
- The crop is under stress in the dry soil when the potential energy of soil water drops below the threshold value.
- The effect of soil water stress can be estimated by water stress coefficient (Ks) multiplied with basal crop coefficient (Kcb).

Computing crop evapotranspiration

Daily water balance



(a) components of balance

- For Estimating irrigation requirements.
- Estimating crop water requirements by calculating the soil water balance of the root zone on daily basis.
- Planning the depth and timing of irrigation
- A daily water balance, expressed in terms of depletion at the end of the day, is:

$$D_{r,i} = D_{r,i-1} - P_i + RO_i - I_i - CR_i + ET_{a,i} + SR_i + DP_i$$

- Where

$D_{r,i}$ = root zone depletion at the end of day i [mm]

$D_{r,i-1}$ = depletion in the root zone at the end of the previous day, i-1 [mm]

P_i = precipitation on day i [mm], limited by maximum daily infiltration rate [mm]

RO_i = surface runoff from the soil surface on day i [mm]

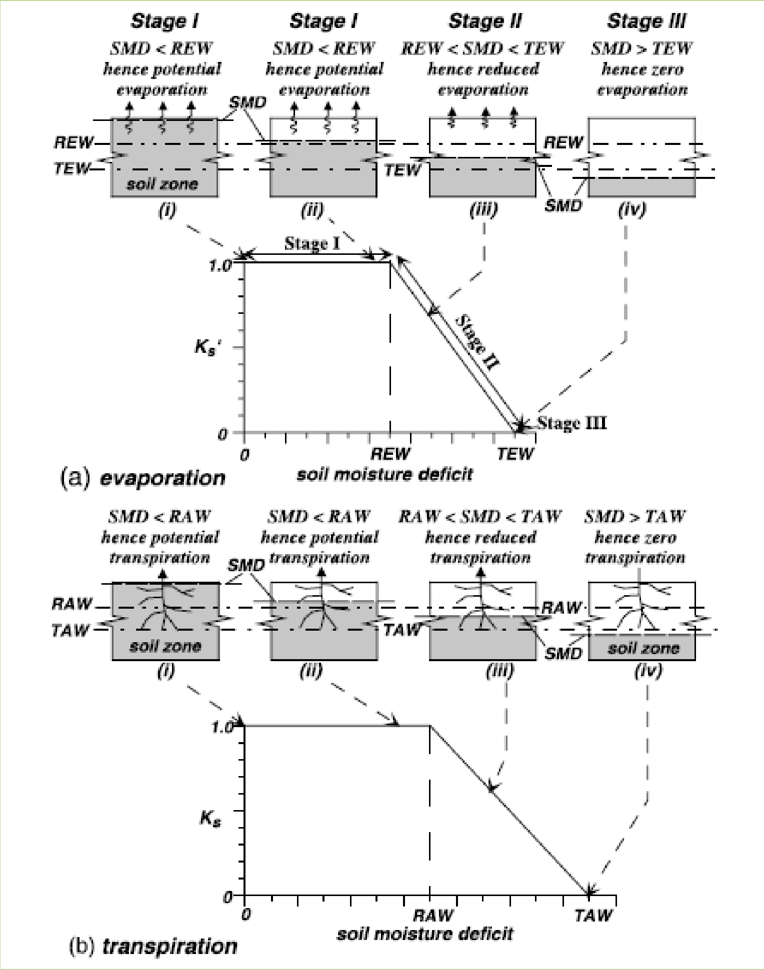
I_i = net irrigation depth on day i that infiltrates the soil [mm]

CR_i = capillary rise from the groundwater table on day i [mm]

$ET_{a,i}$ = actual crop evapotranspiration on day i [mm]

DP_i = water flux out of the root zone by deep percolation on day i [mm]

Reduced evaporation or transpiration due to limited moisture availability resulting from increasing soil moisture deficits:



Source:- Rushton et al., 2005.

- When soil is wet, stress coefficient (Ks) value is maximum and evapotranspiration occurs at potential rate.
- If there is precipitation or irrigation, Ks = 1.
- As the soil surface dries, Ks<1 and when no water is available for evapotranspiration in the top soil, Ks=0.
- To avoid crop water stress, irrigation needs to be applied. Ks can be calculated as follows (Allen et al., 1998; Allen R. G. 2002).
- $K_s = 1 \quad \text{for } D_r \leq RAW$

$$K_s = \frac{TAW - D_{r,i}}{TAW - RAW} = \frac{TAW - D_{r,i}}{(1-p)TAW} \quad \text{for } D_r > RAW$$

- Where, TAW= Total Available Water (mm)

  RAW= Readily Available water (mm)

  $D_{r,\ i}$ = root zone depletion at end of day i (mm)

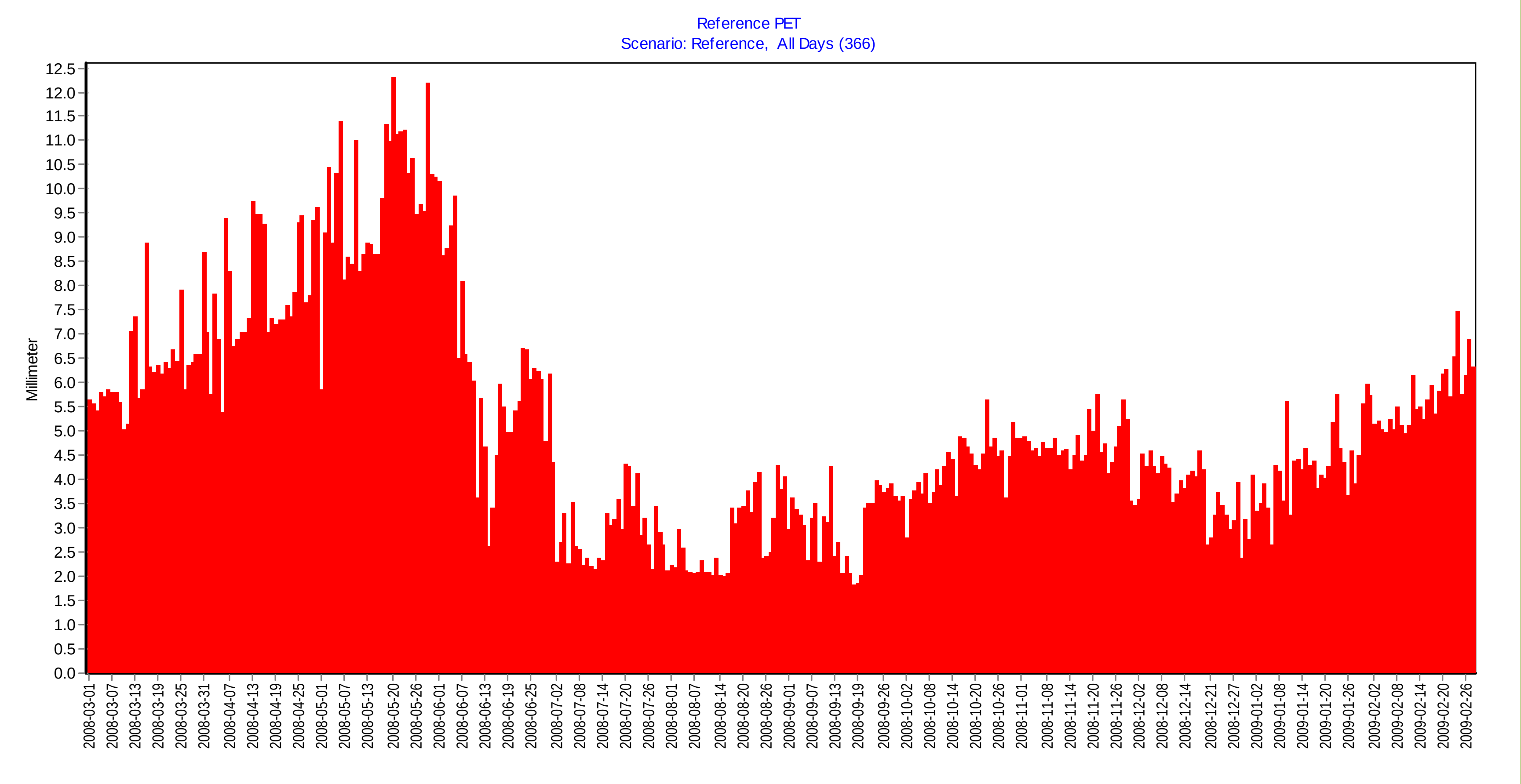
  p = depletion factor

Working out strategies for irrigation

ASE NO.	CROP	PLANTING DATE	HARVESTING DATE	IRRIGATION STRATEGY	
				IRRIGATION SCHEDULING	IRRIGATION AMOUNT
I raditional ractices	Maize	5th July	22nd September	18th ,47th, 60th day	25 mm
	Wheat	1st November	28th February	1st, 6th, 11th, 34th, 46th, 58th, 60th, 72nd, 84th day	60 mm
II Model pecified	Maize	5th July	22nd September	100% RAW	100% Depletion
	Wheat	1st November	28th February	100% RAW	100% Depletion

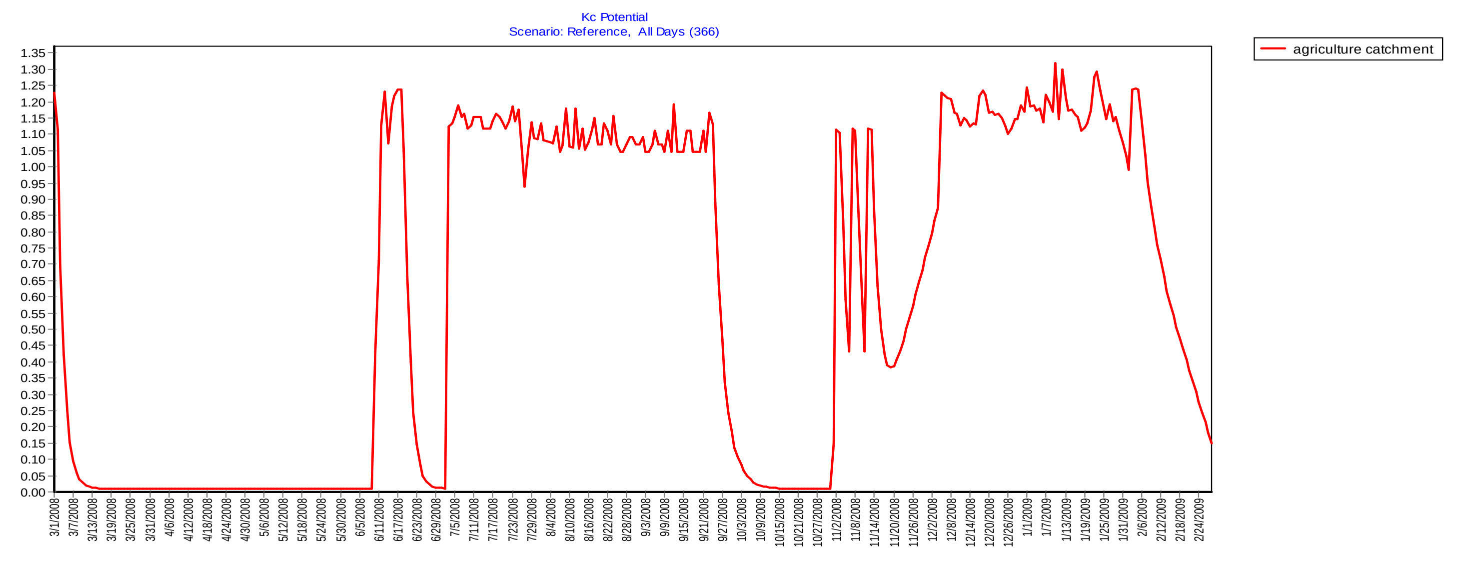
- Irrigation to be applied before or at the moment when readily available water (RAW) is equal or greater than soil moisture depletion (SMD) to avoid crop water stress. i.e. (SMD <= RAW).
- Irrigation applied at fixed interval and fixed amount as per practices followed by localities.
- Irrigation to be applied when crop reaches at a fixed % of soil moisture depletion.
- The irrigation amount can also be determined according to fixed depth, % of deletion, % of RAW and % of TAW.

Reference PET Scenario : All Days (366)



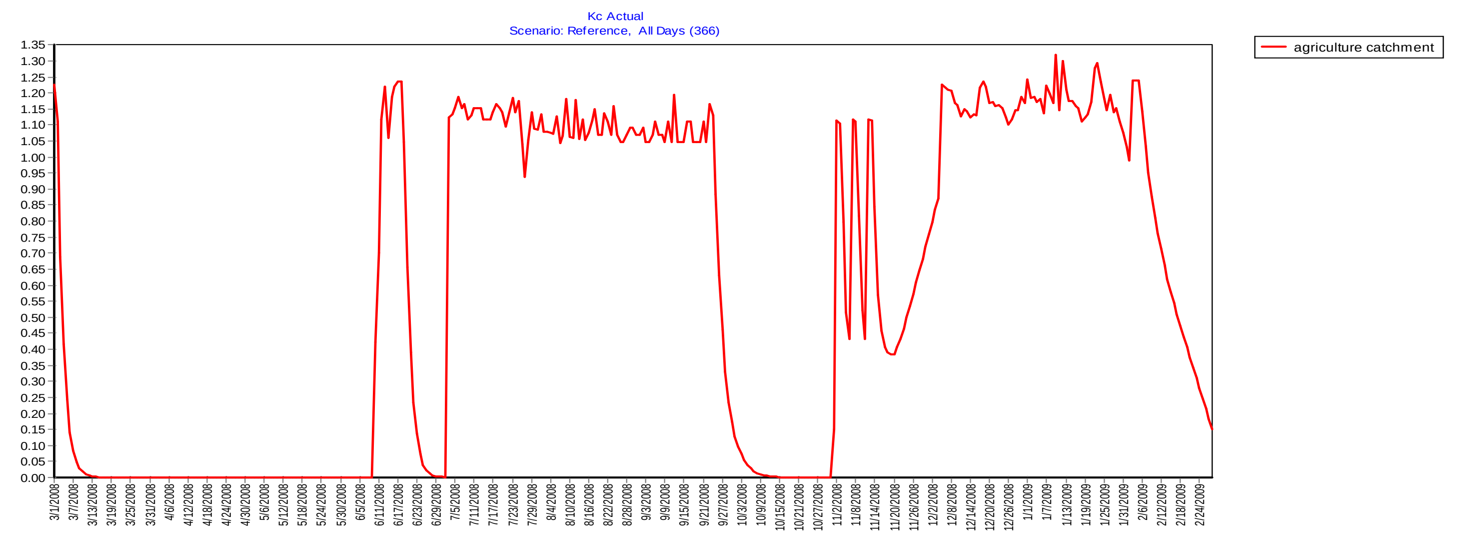
Comparison of potential and actual crop coefficient for case 1

Case 1
Traditional practices
Kc Potential .



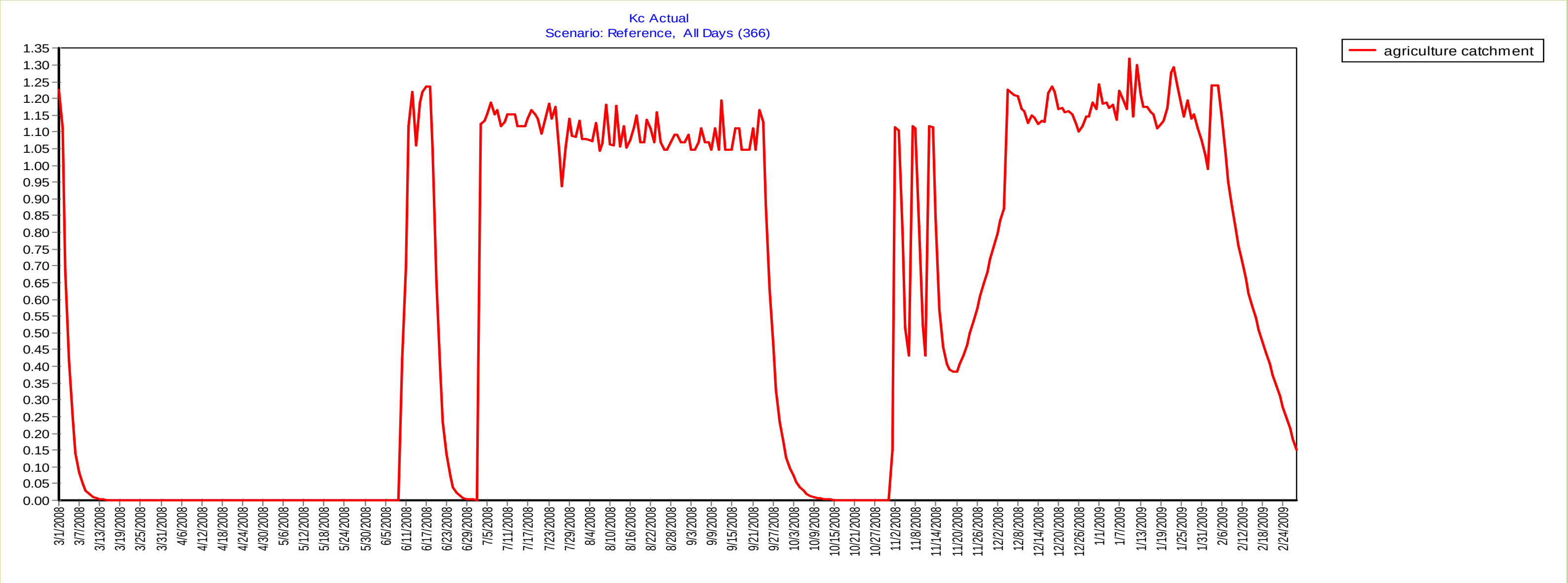
Case 1
Traditional practices
Kc Actual.

It is marginally lesser in initial period of wheat

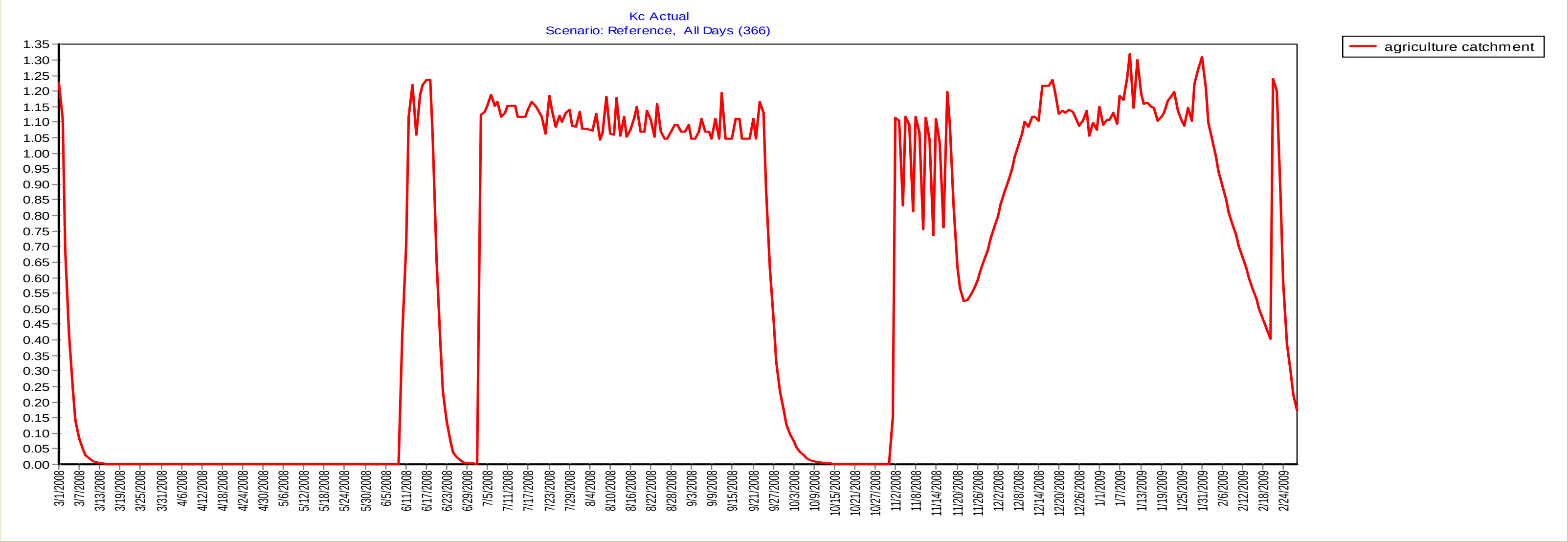


Comparison of actual Crop Coefficient of both cases

Case 1
Traditional practices
Kc actual



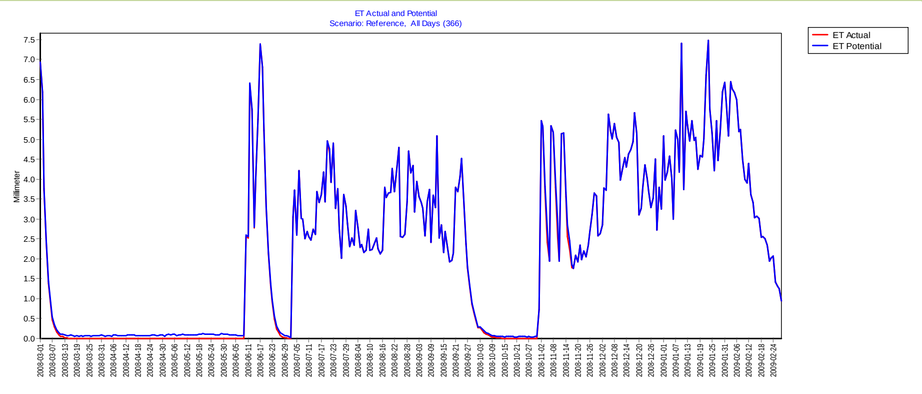
Case 2
Model specified
Kc actual
are marginally higher in initial period



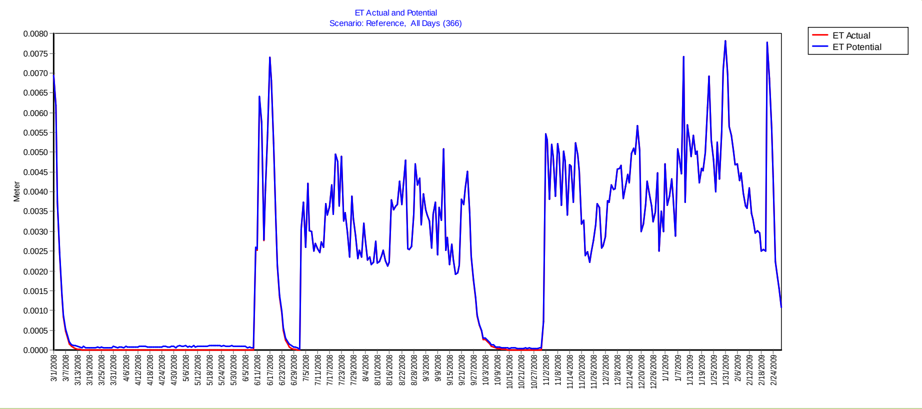
Comparison of ET actual and ET potential of both cases

CASE NO.	CROP	TOTAL ET actual (mm)	TOTAL ET pot
1	Maize	251.12	251.12
	Wheat	478.13	479.82
2	Maize	251.39	251.39
	Wheat	506.01	506.13

Case 1: Traditional practices



Case 2: Model specified



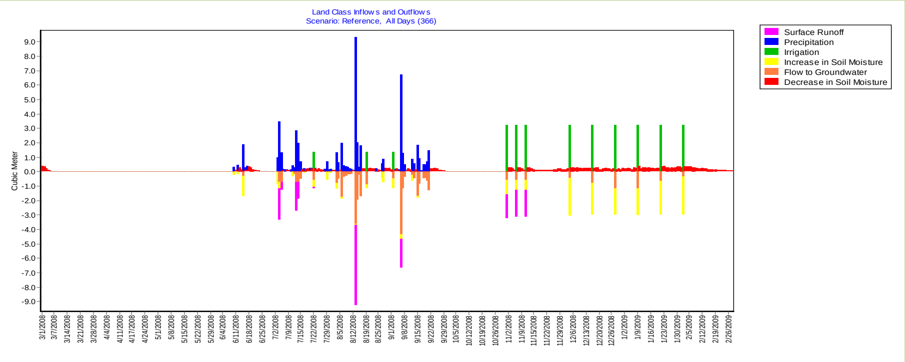
In maize crop, actual evapotranspiration is found same in Case-I and Case-II as this crop is not under water stress in both the cases.

But, in case of wheat crop; the water stress condition has resulted lower value of actual evapotranspiration in Case-I

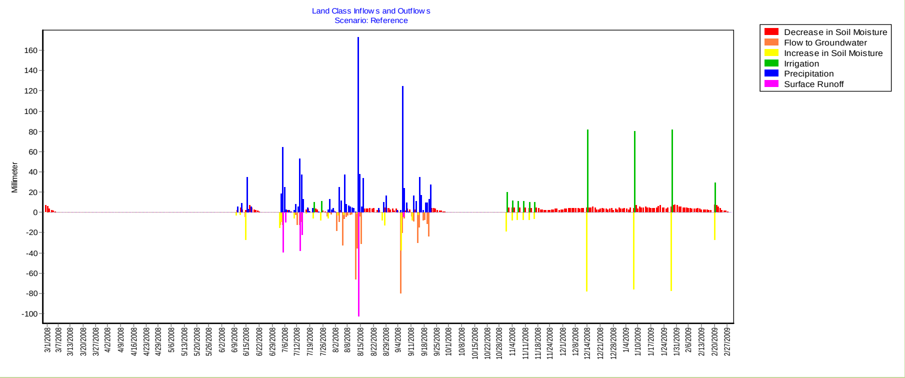
Soil Moisture Balance

CASE NO.	CROP	DECREASE IN SOIL MOISTURE (mm)	TOTAL PRECIPITATION (mm)	TOTAL IRRIGATION* (mm)	TOTAL RUNOFF (mm)	TOTAL FLOW TO GROUND WATER (mm)	INCREASE IN SOIL MOISTURE (mm)
1	Maize	109.74	883	75	211.78	508.42	96.404
	Wheat	446.27	0	540	101.05	108.31	452.91
2	Maize	113.78	883	21.69	178.17	484.23	104.68
	Wheat	470.85	0	349.13	0	0	313.97

Case 1: Traditional practices



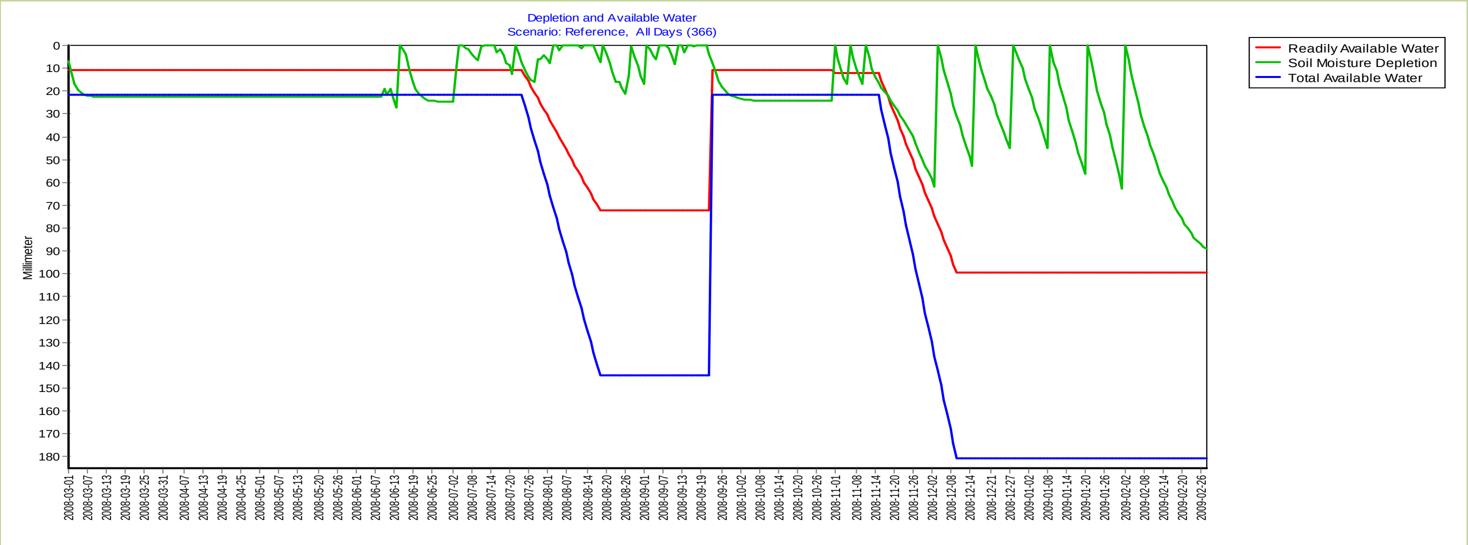
Case 2: Model specified



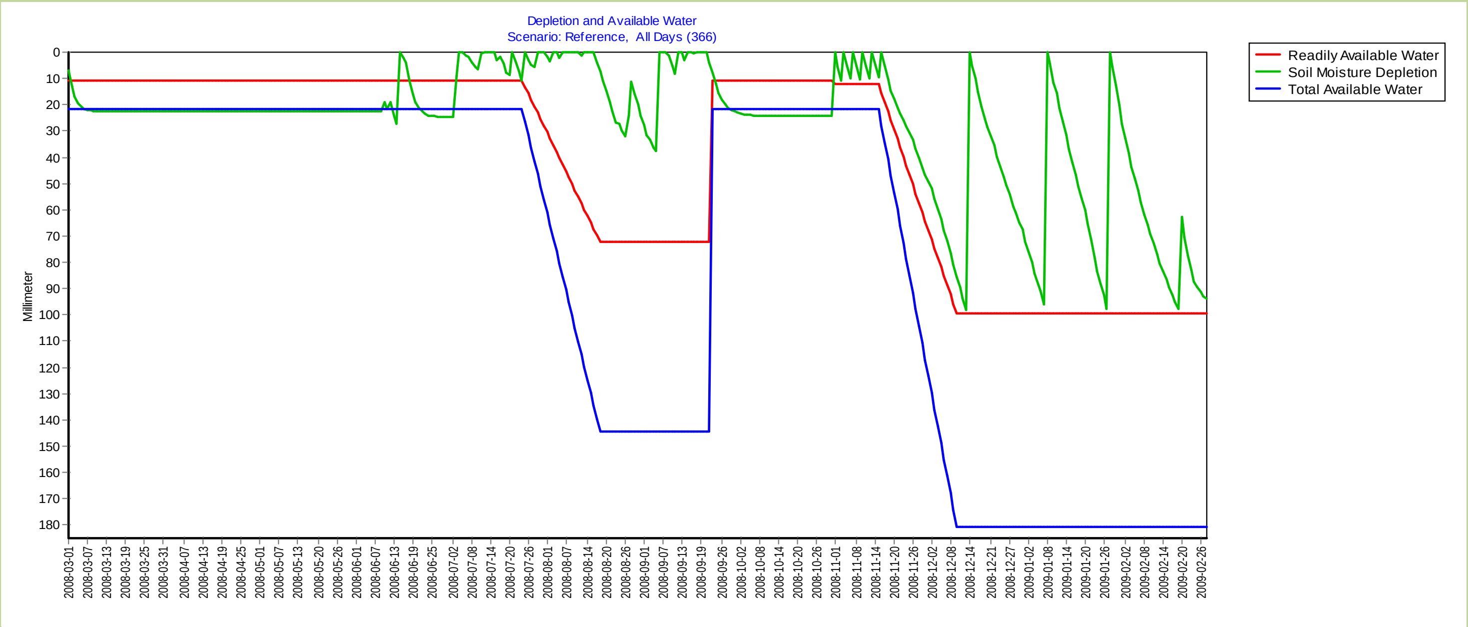
The model specified irrigation strategy prevents runoff and deep percolation

Soil Moisture Depletion, RAW And TAW

Case-I Traditional Practices



Case-II Triggering Irrigation when Soil Moisture Depletion reaches 100% of RAW



Concluding Remarks

- In maize crop, actual evapotranspiration is found same in Case-I and Case-II as this crop is not under water stress in both the cases.
- But, in case of wheat crop; the water stress condition has resulted lower value of actual evapotranspiration in Case-I.
- The model specified irrigation strategy also prevents runoff and deep percolation.
- Thus saving of water can be achieved by application of WEAP in determining irrigation requirements in real time condition.
- The prevention of water stress condition by model application also improves yield of crop

References

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Thank you

Irrigation Strategy for Maize and Wheat Crop

CASE NO.	CROP	PLANTING DATE	HARVESTING DATE	IRRIGATION STRATEGY	
				IRRIGATION SCHEDULING	IRRIGATION AMOUNT
I	Maize	5th July	22nd September	18th ,47th, 60th day	25 mm
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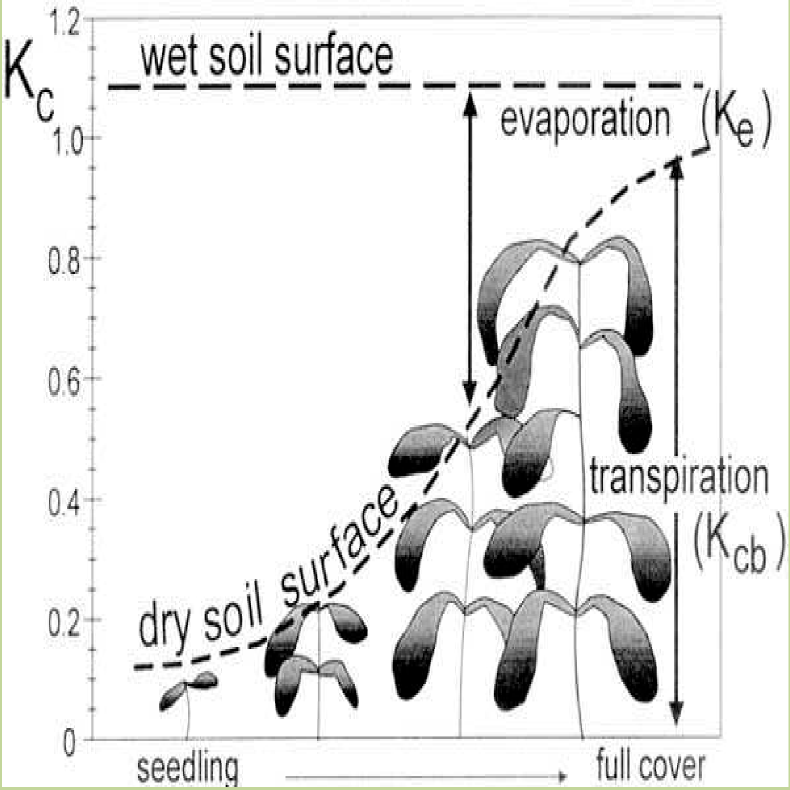
II	Maize	5th July	22nd September	100% RAW	100% Depletion
	Wheat	1st November	28th February	100% RAW	100% Depletion

Motivation of the study

- Complexities involved in estimation of Crop water requirement with different parameters. (Weather, Crop, Soil)
- The intricacy involved in measurement of rainfall and/or irrigation losses by surface run off, percolation beyond root zone and soil moisture use of crops.
- Uncertainties arise in estimating the moisture availability.
- Development in recording meteorological data using automated instruments on daily as well as hourly basis.
- Using this data it is also possible to precisely estimate reference evapotranspiration.
- Using advance model such as Penman Monteith it is possible to integrate all this technology related to data and model to precisely monitor the irrigation process (soil moisture balance).
- The applying the water to the crops when it is not essential; while not applying when it is desirable.

Basal Crop and Soil Evaporation Coefficients

- Kcb represents actual evapotranspiration conditions when the soil surface is dry but sufficient root zone moisture is present to support full transpiration.
- Soil evaporation coefficient (Ke) calculated when the topsoil dries out, and evaporation is less and evaporation reduces in proportion to the amount of water available in surface soil layer (Allen et al., 1998; Allen R. G. 2002; Allen et al., 2005).

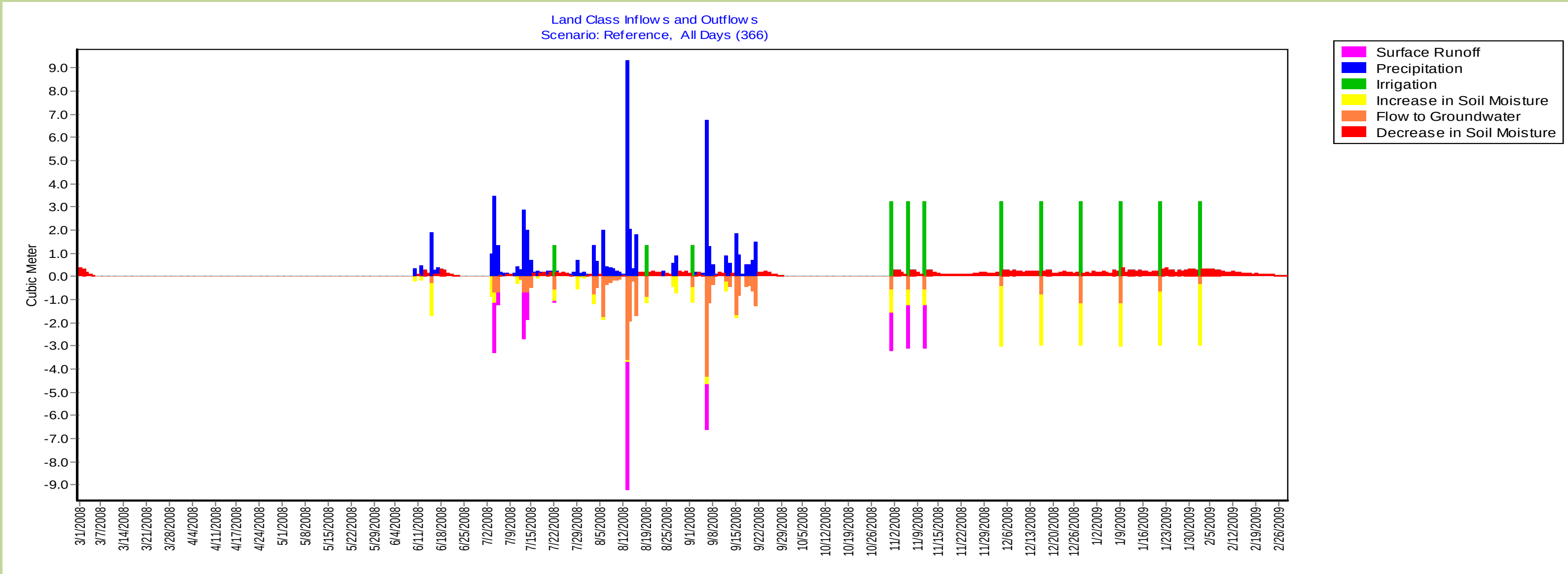


Runoff and Flow to Groundwater during Irrigation of Maize and Wheat

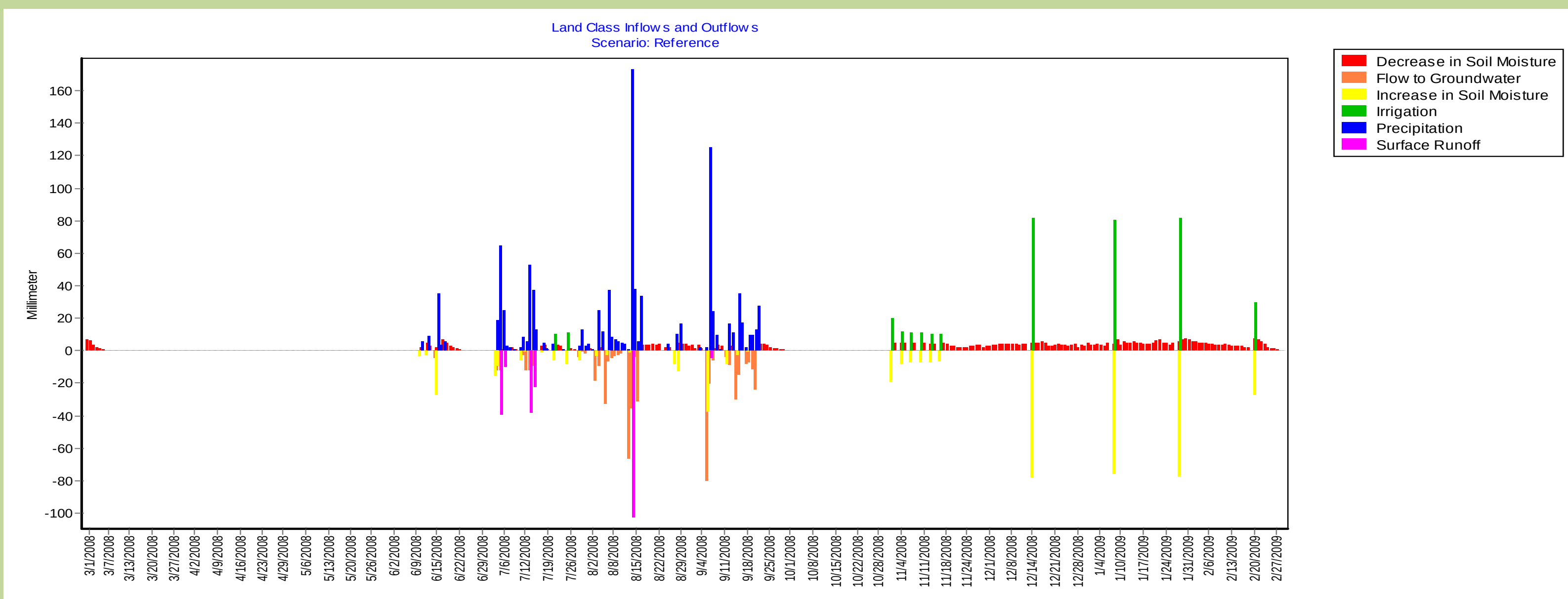
CASE NO.	CROP	TOTAL ETactual (mm)	TOTAL PRECIPITATION (mm)	TOTAL IRRIGATION * (mm)	TOTAL RUNOFF (mm)	TOTAL FLOW TO GROUND WATER (mm)
1	Maize	251.12	883	75	211.78	508.42
	Wheat	478.13	0	540	101.05	108.31
2	Maize	251.39	883	21.69	178.17	484.23
	Wheat	506.01	0	349.13	0	0

Land Class Inflows and Outflows

Case 1



Case 2



- Penman- Monteith Equation:
- $$ETo = \frac{0.408\,\Delta(Rn - G) + \gamma \frac{900}{T + 273} U_2 (es - ea)}{\Delta + \gamma(1 + 0.34U_2)} \quad (1)$$
- Where, ETo =reference evapotranspiration [mm day-^{1}], Rn =net radiation at the crop surface [MJ m^{-2} day^{-1}], G=soil heat flux density [MJ m^{-2} day^{-1}], T= mean daily air temperature at 2 m height [°C], u_2=wind speed at 2 m height [m s^{-1}], e_s=saturation vapour pressure [kPa], e_a=actual vapour pressure [kPa], e_s-e_a=saturation vapour pressure deficit [kPa], Δ=slope vapour pressure curve [kPa $°C^{-1}$], γ=psychrometric constant [kPa $°C^{-1}$].

Working out strategies for irrigation

- Irrigation to be applied before or at the moment when readily available water (RAW) is equal or greater than soil moisture depletion (SMD) to avoid crop water stress. i.e. (SMD <= RAW).
- Irrigation applied at fixed interval and fixed amount as per practices followed by localities.
- Irrigation to be applied when crop reaches at a fixed % of soil moisture depletion.
- The irrigation amount can also be determined according to fixed depth, % of deletion, % of RAW and % of TAW.