WATER HARVESTING FOR DRYLAND FARMING

. . . . Flood-Runoff Farming (FRF)

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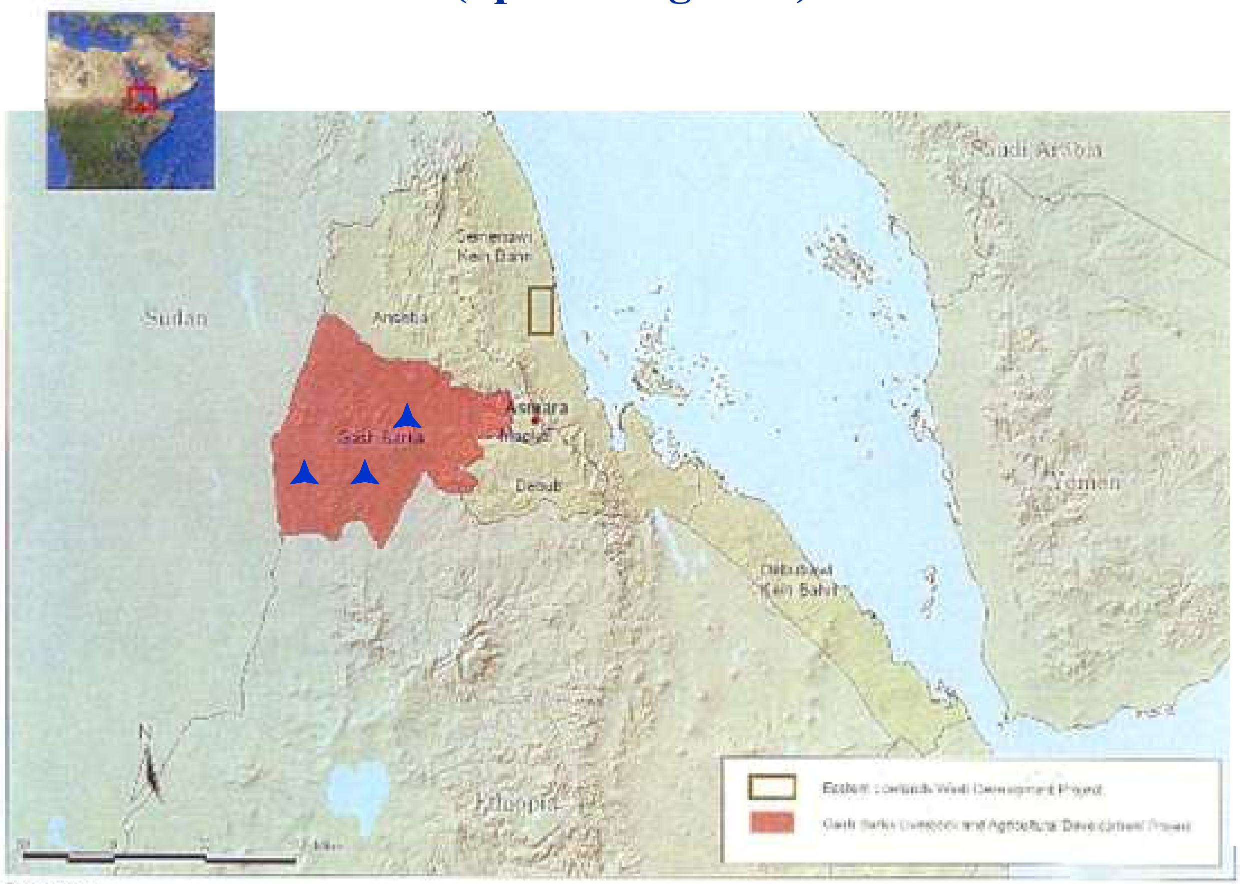
NATUUR- EN LANDBOUWETENSKAPPE

CASE STUDY

Modelling of Soil Moisture Storage in Flood Water Management in Western Lowland of Eritrea

(Spate Irrigation)



Source: FAO

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Introduction

- Very ancient and still not very well known or ignored to be deeply assessed & evacuated

- Recently FAO released a **Guidelines on Spate Irrigation**

"FAO Irrigation & Drainage paper 65" *www.fao.spateguidelines.org*

- Constitute the main source of subsistence for many farmers in arid & semi-arid areas of Asia, Africa and Latin America.

e.g. Area under Spate Irrigation for some countries

	FAO (AQUASTAT)	Expert meeting 2008
Algeria	**56050**	**56000**
Eritrea	**17490**	**17000**
Ethiopia	**-**	**140000**
Iran	**-**	**419500**
Moroco	**26000**	**165000**
Pakistan	**720000**	**640000**
Tunisia	**27000**	**1000**
Yemen	**218000**	**117000**

Source FAO 2010

The target of this case study is to explain a bit better this technique to a large public starting from farmers experience in Western Lowlands of Eritrea

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What is spate Irrigation / Diversion schemes?

- "Flood water harvesting system" harnessing flood water from ephemeral streams &diverting the water to agricultural fields through earthen or concrete canals

- Established in the plain around mountains or hilly area in order to collect runoff allowing low-lying fields to store moisture during cropping season

- Pre-planting system, in which the crop season follows the flood season

Justification

✓ Spate Irrigation development is carried out in hot arid & semi arid area, where **evapotranspiration greatly exceeds rainfall.**

✓ In western low land (Arid & Semi arid areas) the only water available for irrigation comes from **seasonal spate flows in ephemeral rivers**.

✓ In these circumstances improving existing communal spate irrigation systems and opening up new spate irrigated areas are attractive development options.

✓ Command area may range from any thing between few hectares to over 20,000 ha, It provides the livelihood for large numbers of economically marginal people.

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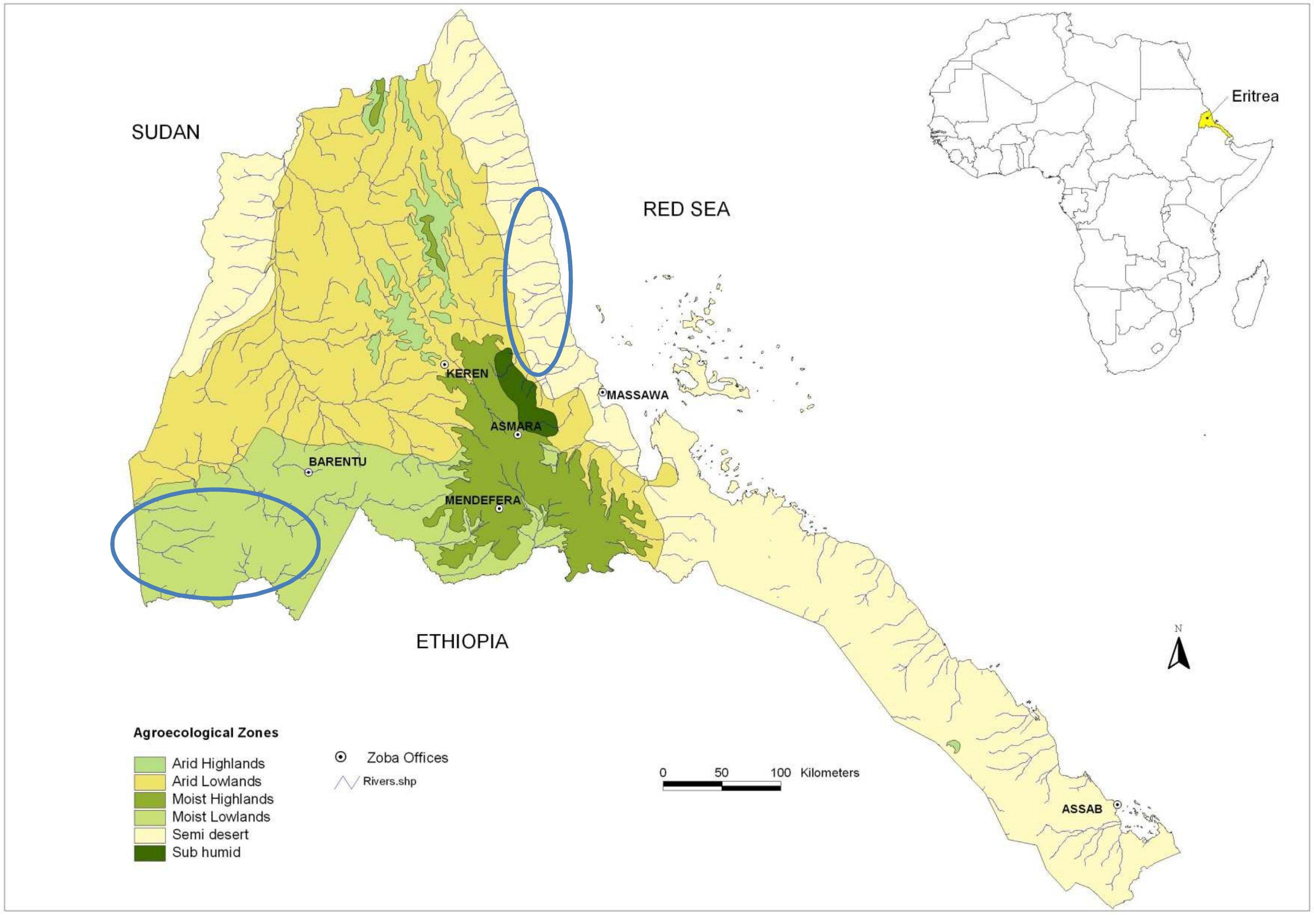
Agro ecological Zones



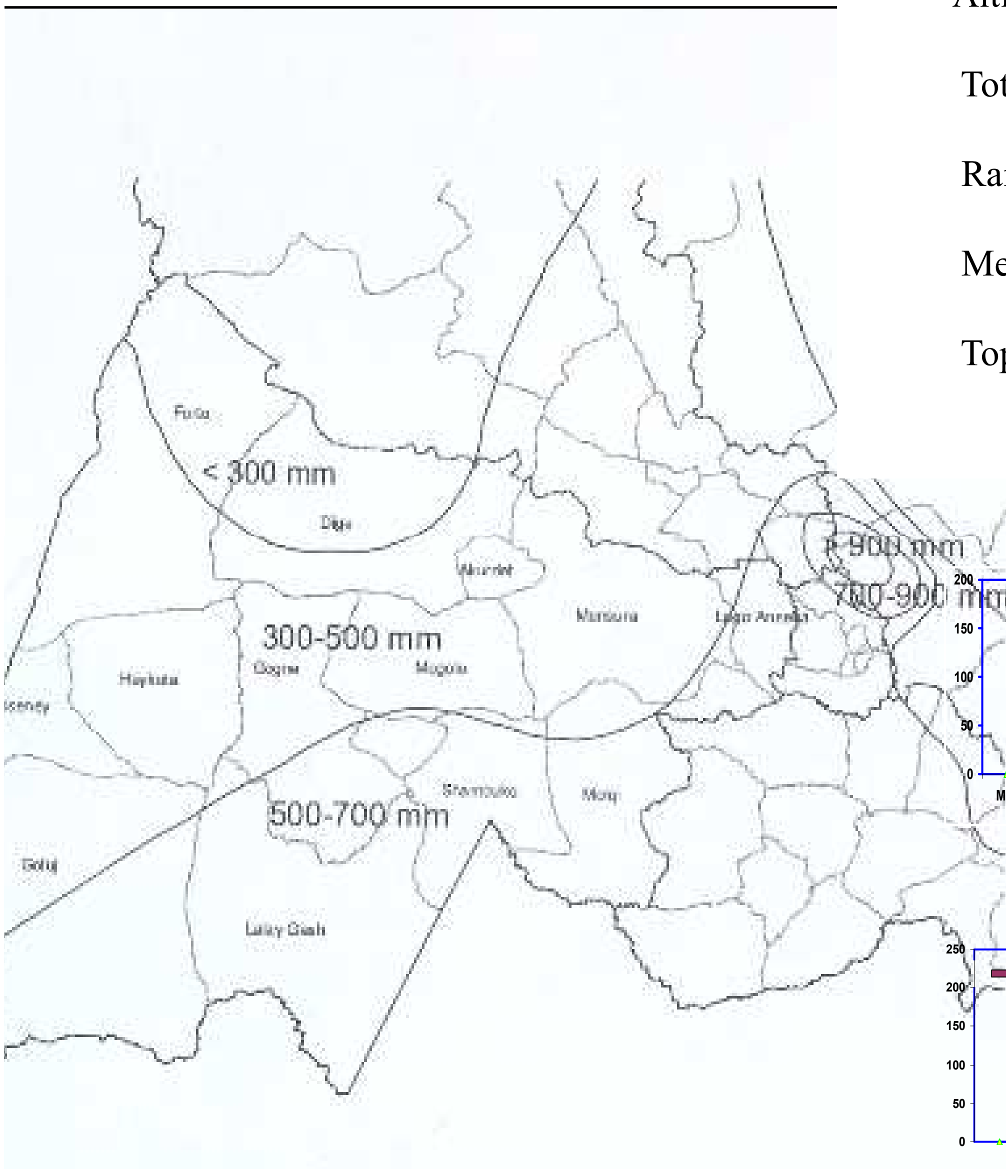
Rainfall: Erratic and unevenly distributed, unreliable spatial & temporal.

Water Resorces Limited mainly seasonal rivers

Soils Highly variable with high erosion (silt clay loam – Sandy loam)

Rainfed subsitatnce farming Yield is still low

The Physical Environment



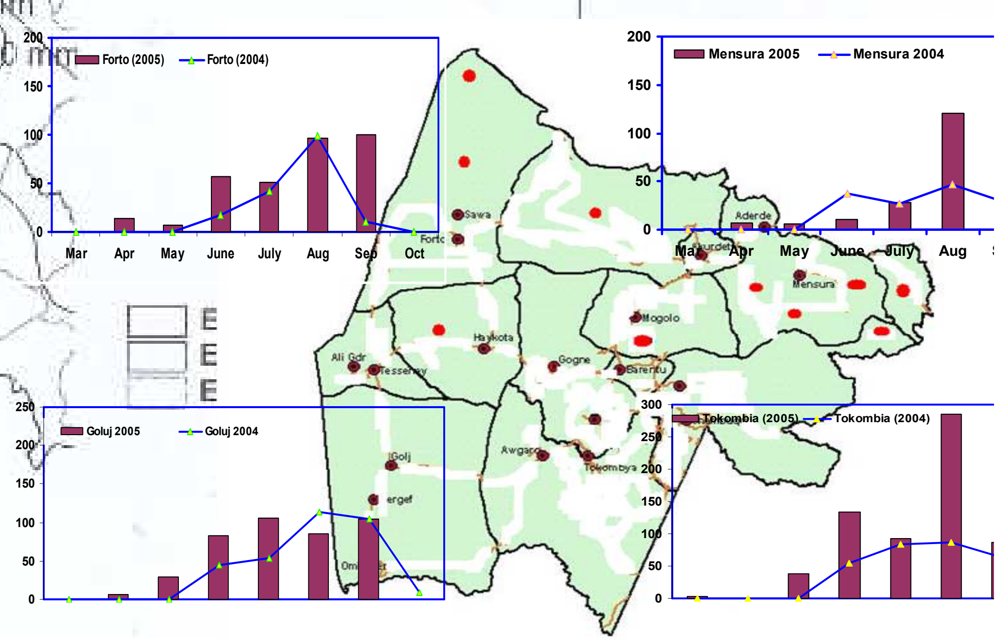
Altitude: 500 – 1200 m.a.s.l

Total annual rainfall: 200 – 550 mm

Rainfall pattern: Uni-modal June – Sep.

Mean annual temperature: 17 ^{0}C - 41 ^{0}C

Topography :
- High Potential Plains with
- Mountainous rugged terrain
- Small & Big Rivers



Soils

- **Vertsol :** mainly in south western lowlands result of sediments transport & depositing pattern
- **Fluvisol;** developed in the alluvial soils along the river basin

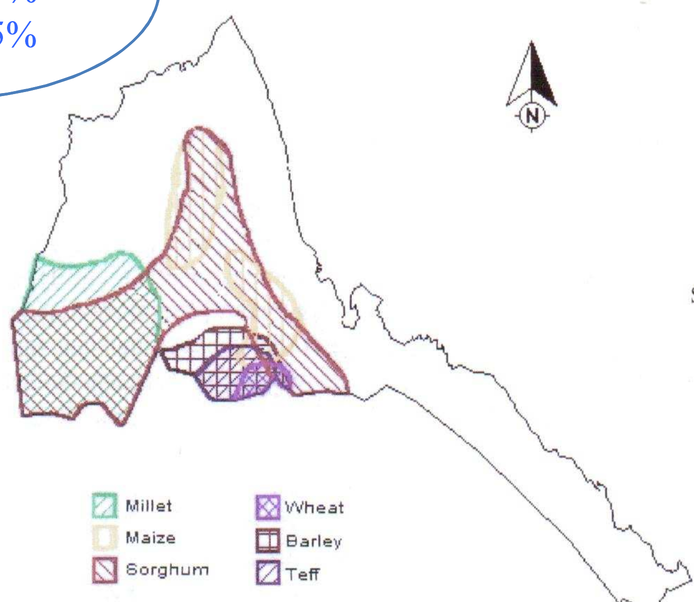
- Generally good water holding capacity with relatively moderate infiltration rate

The main production systems

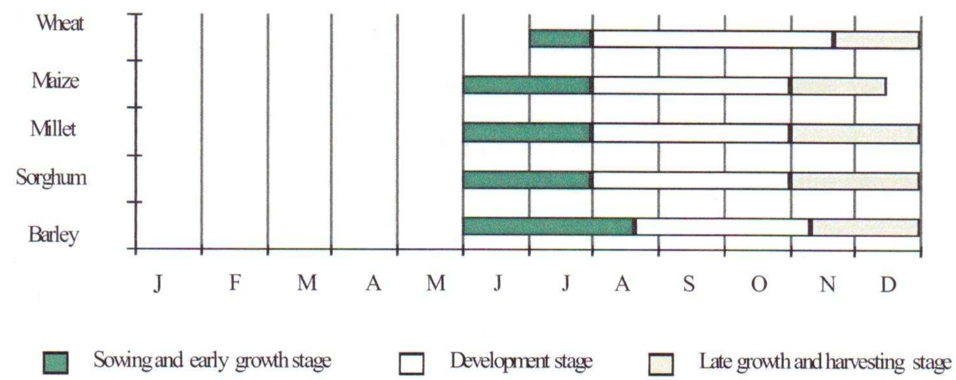
- Semi sedentary pastoralists (mainly in low rainfall areas)
- Sedentary agro pastoral production system, where crop production is the main source of subsistence.

Sorghum= 80%
Millet= 15%
Others= 5%

Crop Zone



Cropping Calendar



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Management of Spate Flood Water

- Major floods during June – September

- Farmers can start planting only after irrigation has taken place , but

- Highly unpredictable:
  - **Timing**
  - **Volume**
  - **Number of floods**

- Irrigation System:

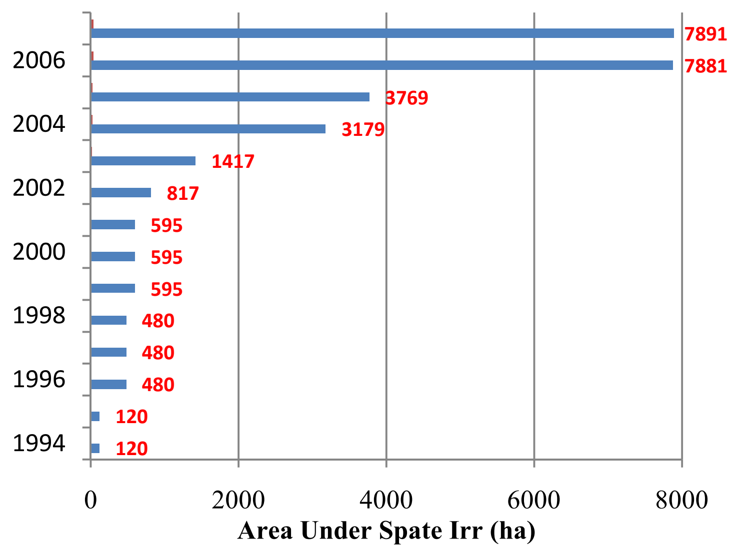
1. **Controlled:** water distribution to refer to a system, where the main diversion feeds to the main canal – feed secondary canal s- - - feed to group of farmers fields with division boxes

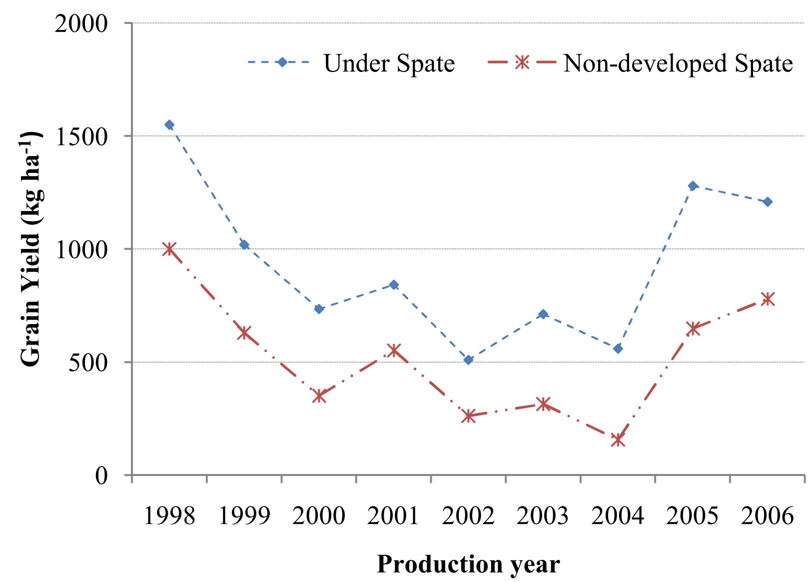
2. **Uncontrolled;** directly fed from the weir structure to the irrigated field without distribution canals


Controlled
Uncontrolled

Potential & Development in Western Lowlands

- Like other arid & dry farming it has an important networking of ephemeral rivers
- Even during most of the dry seasons can carry an amount of water for a few hours or days after rare rain, that often comes in the form of violent storms
- However small scale agro-shepherdess exploits the flood water, by diverted towards cultivated plot, using dunes, branches (*Sheayale),* stones & soil & by using sand filled sacks.
- Small to medium and some large schemes extended since 2002/03



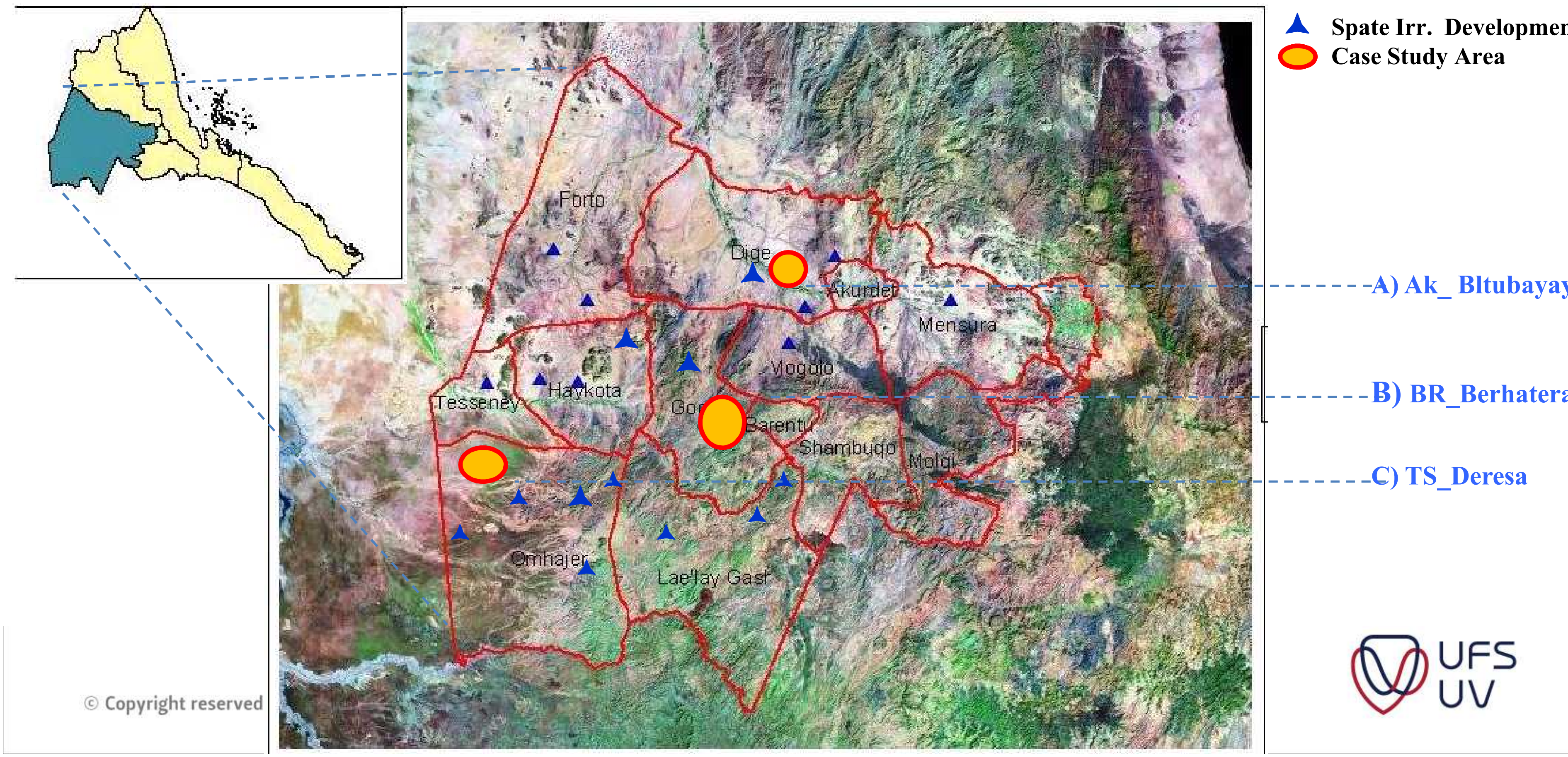


Source; Report MoA, Eritrea

Description of the Case Study Areas

Description	A) AK_Bultbuyay	B} BR_Berhatera	C) TS_Deresa
Climate			
Tmax(°C)	38	35	33
Tmin(°C)	20	17	18
RF (mm)	253	288	589
^{ETo} (mm)	2200	2155	2060
AI	0.11	0.13	0.18
Soils (for all locations)			
Type	Silt clay Loam	Silt loam	Sandy Loam
Depth (m)	1.6-2.0	1.5, 1.8	1.6-2.0
BD (Mg m^{-3})			
Clay (%)	30-40	25	10
Silt (%)	60-70	70	85
Sand (%)	-	5	6
OC (%)	Very low	Very low	Very low

Distribution of Spate Irrigation Structures in Western lowlands



Problems / Challenges

- Built without the knowledge of rainfall volume from the catchment
- Improper quantifying of stream flow discharge or sediment load
- Without any sort of sediment ejectors or gravel or sediment traps
- Accumulation of sediments at the upstream of the head work & in the main canal intake & substantially reduce the amount of water being diverted.
- Width, depth & Length of the canals & gates of division boxes may not properly designed.
- disadvantages of un-gated division boxes for easy management purposes

Main concern?

- Lack of underpinned information for different crop irrigation requirement , irrigation losses and total available water as a soil moisture storage during cropping season
- Hard to make estimations of water balance components for flood water management

Focus of the case study

- To simulate sorghum crop irrigation requirement and irrigation looses under conditions of high and low plant available water at the root zone using a SAP WAT3 programme.
- To estimate soil moisture storage (SMS) and crop evapotranspiration (ET) using simple water balance model of the root zone for different flood occurring scenarios

Methodology

Conceptual back ground of SAPWAT3

- Not crop growth model, but used for planning and management tool relaying mainly on climate and crop database
- Provides a framework within which crop water requirement is estimated
- Utilize in preliminary planning discussions with users and can plan how much flood water required as prerequisite for group flood water sharing spate irrigated farmers

Computation Procedure

- Running water balance model of the root zone per time step (daily)
- Uniform distribution water of the root zone at depth of 1.2 m
- The water balance of the root zone is expressed in terms of **saturation deficit = amount of water required** to saturate the root zone (S) and written as;

$$S_{t+1} = S_t + \Delta t(P_{t+1} + I_{t+1} - D - E_{t+1})$$

Where:

$$\Delta t = time - step...(day)$$
$$P = precipitation...(mm)$$
$$I = Flood - Irrigation...(mm)$$
$$D = Deep - perculation...(mm)$$
$$E_0 = Soil - Evapoartion...(mm)$$

- For Soil Evaporation an empirical function of Boesten Stroosnijder (1986) were adopted :

$$\sum Ea = \beta' \sqrt{Epot}$$

Where:

$$\sum Ea = cumulative - actual - evapoartion...(mm)$$
$$\beta' = soil - specific - parameter...(mmd^{-1/2})... = 3.5mmd^{-1/2}$$

Model Input and Outputs

Model Inputs:

- daily climate data (CLIMWAT)
- Soil moisture characteristics, FC, WP, TAW, RAW
- Evaporation depth
- Crop characteristics

Model Out puts

- Reference evaporation and crop evapotranspiration in mmd^{-1}
- Irrigation water requirement in mm
- Irrigation losses in mm
- Saturation deficit of the root zone S in mm
- Soil moisture storage of the root zone SMS in mm

mm

Irrigation Schedule Scenarios formulation

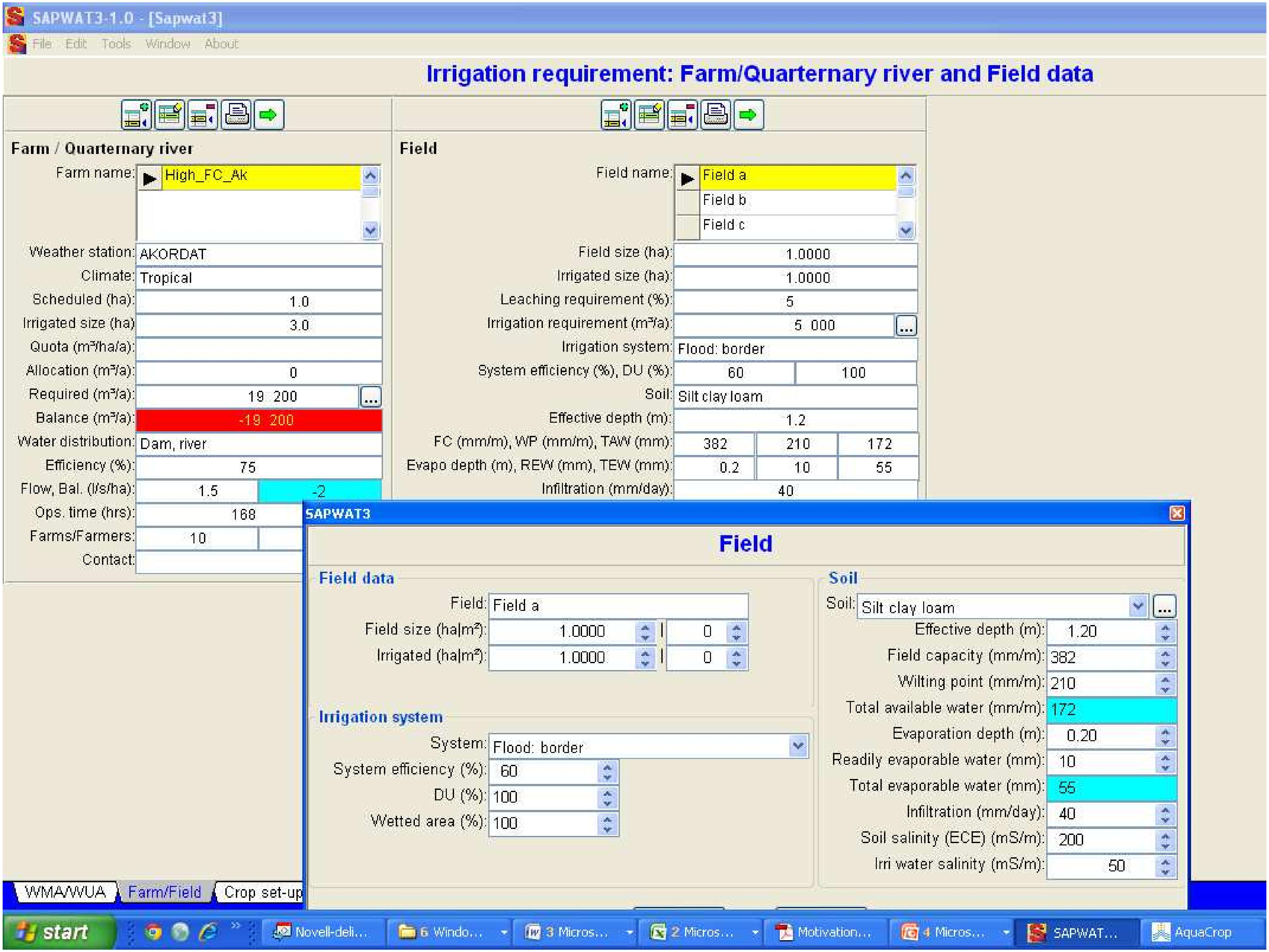
1. **Highly Likely Scenario :** a field receives 2 irrigation turns in July & each one turn in June & August = 4

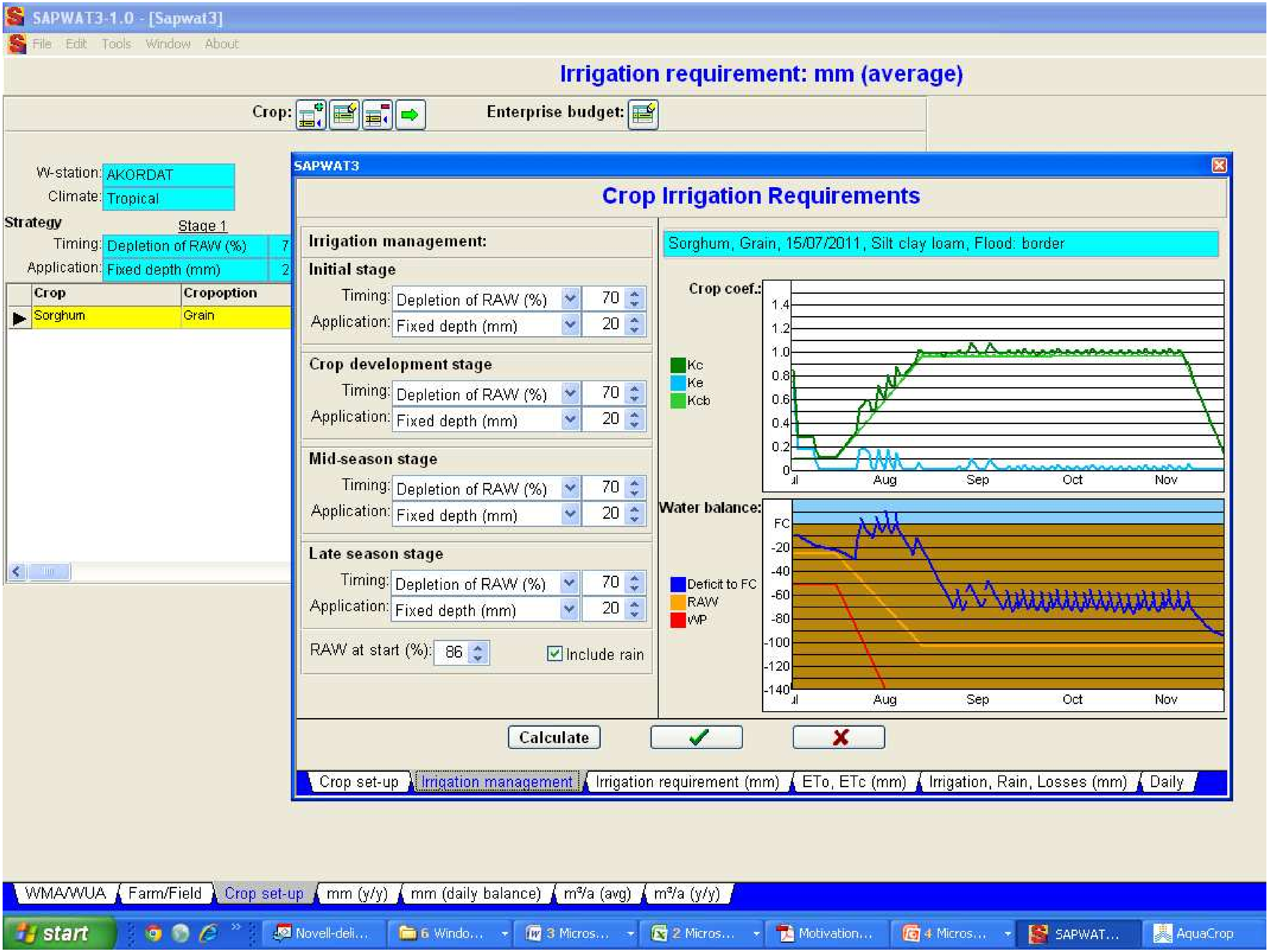
2.Less Likely Scenario: a field is irrigated once turn on each flood month (June, July & August) = 3

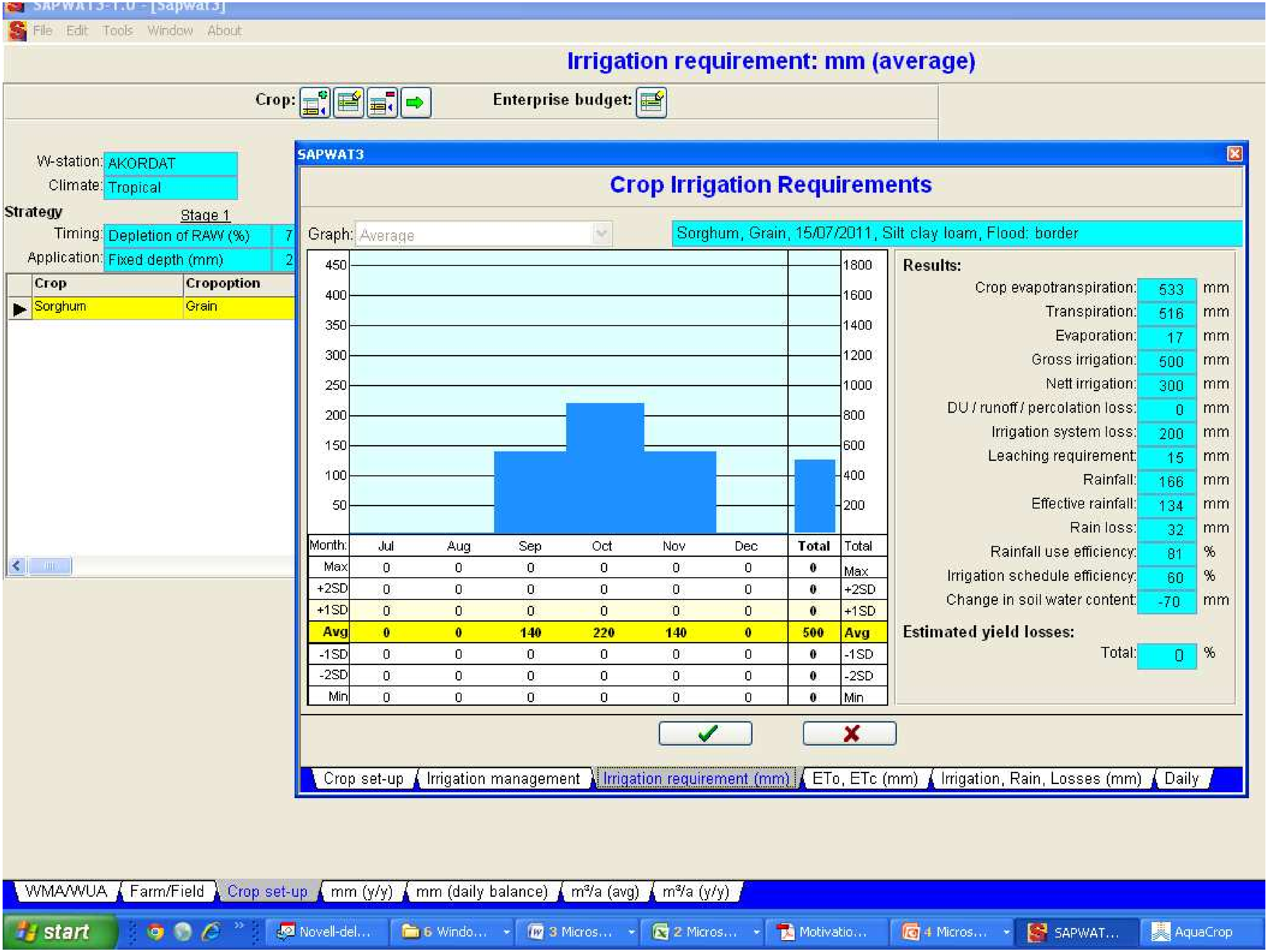
3.Unlikely , yet possible scenario: a field gets one in July and other one in June or August = 2

Simulation Assumptions

- This scenarios are based on farmers observations, that Mid-June - Mid-Aug is effective flood season
- July is the month at least 50% of the total number of floods occurs
- The irrigation gift (I) is 60 mm, but large at once to be applied, then use 3 consecutive days of 30, 20 & 10 mm
- For all scenarios 2- late flood irrigation of small amount (10 & 5 mm) were considered
- Use two sorghum cultivars (short maturing & medium maturing) with 105 and 125 growing days


SAPWAT3-1.0 - [Sapwat3]
File Edit Tools Window About
Irrigation requirement: Farm/Quarternary river and Field data
Farm / Quarternary river
Farm name: High_FC_Ak
Weather station: AKORDAT
Climate: Tropical
Scheduled (ha): 1.0
Irrigated size (ha) 3.0
Quota (m³/ha/a):
Allocation (m³/a): 0
Required (m³/a): 19 200
Balance (m³/a): -19 200
Water distribution: Dam, river
Efficiency (%): 75
Flow, Bal. (l/s/ha): 1.5 -2
Ops. time (hrs): 168
Farms/Farmers: 10
Contact:
Field
Field name: Field a
Field b
Field c
Field size (ha): 1.0000
Irrigated size (ha): 1.0000
Leaching requirement (%): 5
Irrigation requirement (m³/a): 5 000
Irrigation system: Flood: border
System efficiency (%), DU (%): 60 100
Soil: Silt clay loam
Effective depth (m): 1.2
FC (mm/m), WP (mm/m), TAW (mm): 382 210 172
Evapo depth (m), REW (mm), TEW (mm): 0.2 10 55
Infiltration (mm/day): 40
SAPWAT3
Field
Field data
Field: Field a
Field size (ha|m²): 1.0000 0
Irrigated (ha|m²): 1.0000 0
Irrigation system
System: Flood: border
System efficiency (%): 60
DU (%): 100
Wetted area (%): 100
Soil
Soil: Silt clay loam
Effective depth (m): 1.20
Field capacity (mm/m): 382
Wilting point (mm/m): 210
Total available water (mm/m): 172
Evaporation depth (m): 0.20
Readily evaporable water (mm): 10
Total evaporable water (mm): 55
Infiltration (mm/day): 40
Soil salinity (ECE) (mS/m): 200
Irri water salinity (mS/m): 50
WMA/WUA Farm/Field Crop set-up
start
Novell-deli... 6 Windo... 3 Micros... 2 Micros... Motivation... 4 Micros... SAPWAT... AquaCrop


SAPWAT3-1.0 - [Sapwat3]
File Edit Tools Window About
Irrigation requirement: mm (average)
Crop:
Enterprise budget:
W-station: AKORDAT
Climate: Tropical
Strategy
Stage 1
Timing: Depletion of RAW (%)
Application: Fixed depth (mm)
Crop
Cropoption
Sorghum
Grain
SAPWAT3
Crop Irrigation Requirements
Irrigation management:
Initial stage
Timing: Depletion of RAW (%) 70
Application: Fixed depth (mm) 20
Crop development stage
Timing: Depletion of RAW (%) 70
Application: Fixed depth (mm) 20
Mid-season stage
Timing: Depletion of RAW (%) 70
Application: Fixed depth (mm) 20
Late season stage
Timing: Depletion of RAW (%) 70
Application: Fixed depth (mm) 20
RAW at start (%): 86
Include rain
Sorghum, Grain, 15/07/2011, Silt clay loam, Flood: border
Crop coef.:
Kc
Ke
Kcb
Aug
Sep
Oct
Nov
Water balance:
Deficit to FC
RAW
WP
FC
Calculate
Crop set-up
Irrigation management
Irrigation requirement (mm)
ETo, ETc (mm)
Irrigation, Rain, Losses (mm)
Daily
WMA/WUA
Farm/Field
Crop set-up
mm (y/y)
mm (daily balance)
m³/a (avg)
m³/a (y/y)
start
SAPWAT...
AquaCrop


SAPWAT3-1.0 - [Sapwat3]
File Edit Tools Window About
Irrigation requirement: mm (average)
Crop:
Enterprise budget:
W-station: AKORDAT
Climate: Tropical
Strategy
Stage 1
Timing: Depletion of RAW (%)
Application: Fixed depth (mm)
Crop
Cropoption
Sorghum
Grain
SAPWAT3
Crop Irrigation Requirements
Graph: Average
Sorghum, Grain, 15/07/2011, Silt clay loam, Flood: border
Month: Jul Aug Sep Oct Nov Dec Total Total
Max 0 0 0 0 0 0 0 Max
+2SD 0 0 0 0 0 0 0 +2SD
+1SD 0 0 0 0 0 0 0 +1SD
Avg 0 0 140 220 140 0 500 Avg
-1SD 0 0 0 0 0 0 0 -1SD
-2SD 0 0 0 0 0 0 0 -2SD
Min 0 0 0 0 0 0 0 Min
Results:
Crop evapotranspiration: 533 mm
Transpiration: 516 mm
Evaporation: 17 mm
Gross irrigation: 500 mm
Nett irrigation: 300 mm
DU / runoff / percolation loss: 0 mm
Irrigation system loss: 200 mm
Leaching requirement: 15 mm
Rainfall: 166 mm
Effective rainfall: 134 mm
Rain loss: 32 mm
Rainfall use efficiency: 81 %
Irrigation schedule efficiency: 60 %
Change in soil water content: -70 mm
Estimated yield losses:
Total: 0 %
Crop set-up
Irrigation management
Irrigation requirement (mm)
ETo, ETc (mm)
Irrigation, Rain, Losses (mm)
Daily
WMA/WUA
Farm/Field
Crop set-up
mm (y/y)
mm (daily balance)
m³/a (avg)
m³/a (y/y)
start
SAPWAT...
AquaCrop

SAPWAT3-1.0 - [Sapwat3]

File Edit Tools Window About

Irrigation requirement: mm (average)

Crop: Enterprise budget:

W-station: AKORDAT
Climate: Tropical

Strategy Stage 1

Timing: Depletion of RAW (%) 7
Application: Fixed depth (mm) 2

Crop	Cropoption
Sorghum	Grain

SAPWAT3

Crop Irrigation Requirements

Sorghum, Grain, 15/07/2011, Silt clay loam, Flood: border

DateTime	G_Day	Cover	Height	Roots	Depl.	Rain	R_loss	IrriGro	S_loss	P_Los	Leach	IrriNet	E_loss	RAW	RZD	ETo
15/07/2011	1	0.85	0.02	0.30	0.68	20	0	0	0	0	0	0	4	35	9	5.6
16/07/2011	2	0.85	0.03	0.30	0.68	0	0	0	0	0	0	0	1	35	10	5.5
17/07/2011	3	0.85	0.03	0.30	0.68	0	0	0	0	0	0	0	1	35	12	5.5
18/07/2011	4	0.85	0.04	0.30	0.68	0	0	0	0	0	0	0	1	35	13	5.5
19/07/2011	5	0.85	0.05	0.30	0.68	0	0	0	0	0	0	0	1	35	15	5.5
20/07/2011	6	0.85	0.06	0.30	0.68	0	0	0	0	0	0	0	1	35	16	5.5
21/07/2011	7	0.85	0.07	0.30	0.68	0	0	0	0	0	0	0	1	35	18	5.5
22/07/2011	8	0.85	0.07	0.30	0.68	0	0	0	0	0	0	0	0	35	19	5.5
23/07/2011	9	0.85	0.08	0.30	0.68	0	0	0	0	0	0	0	0	35	19	5.4
24/07/2011	10	0.85	0.09	0.30	0.68	0	0	0	0	0	0	0	0	35	20	5.4
25/07/2011	11	0.85	0.10	0.30	0.68	0	0	0	0	0	0	0	0	35	21	5.4
26/07/2011	12	0.85	0.10	0.30	0.68	0	0	0	0	0	0	0	0	35	21	5.4
27/07/2011	13	0.85	0.11	0.30	0.68	0	0	0	0	0	0	0	0	35	22	5.4
28/07/2011	14	0.85	0.12	0.30	0.68	0	0	0	0	0	0	0	0	35	22	5.4
29/07/2011	15	0.85	0.16	0.33	0.67	0	0	0	0	0	0	0	0	38	23	5.4
30/07/2011	16	0.85	0.20	0.36	0.66	0	0	0	0	0	0	0	0	42	24	5.3

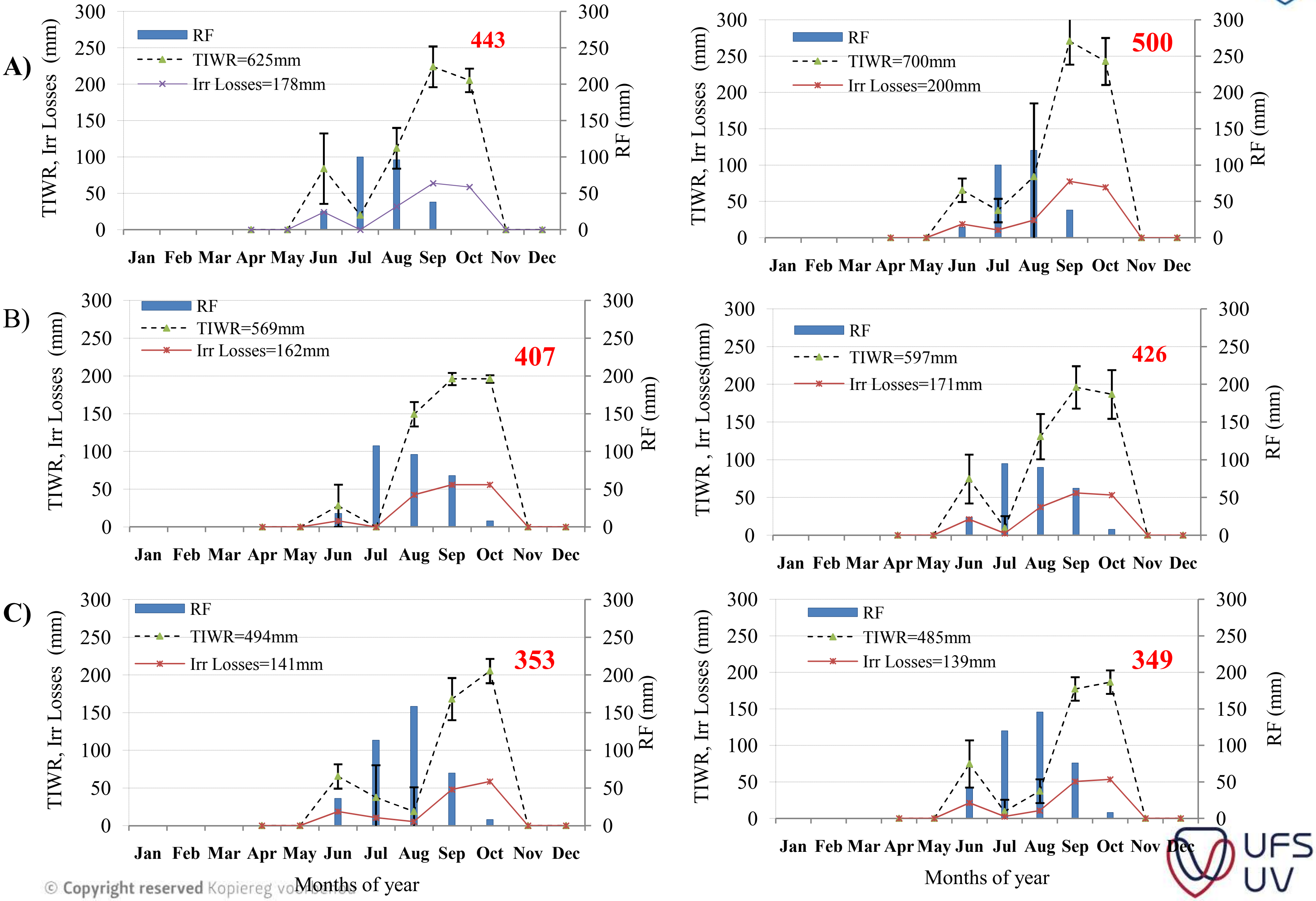
Crop set-up | Irrigation management | Irrigation requirement (mm) | ETo, ETc (mm) | Irrigation, Rain, Losses (mm) | Daily

WMA/WUA | Farm/Field | Crop set-up | mm (y/y) | mm (daily balance) | m³/a (avg) | m³/a (y/y)

Results

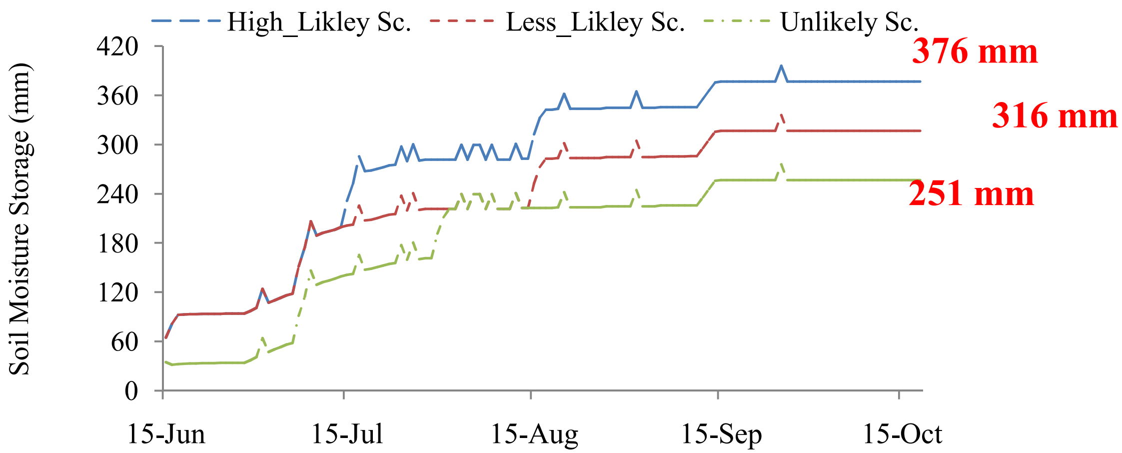
Irrigation Water Requirement & Losses

High Plant Available water | **Low Plant Available Water**

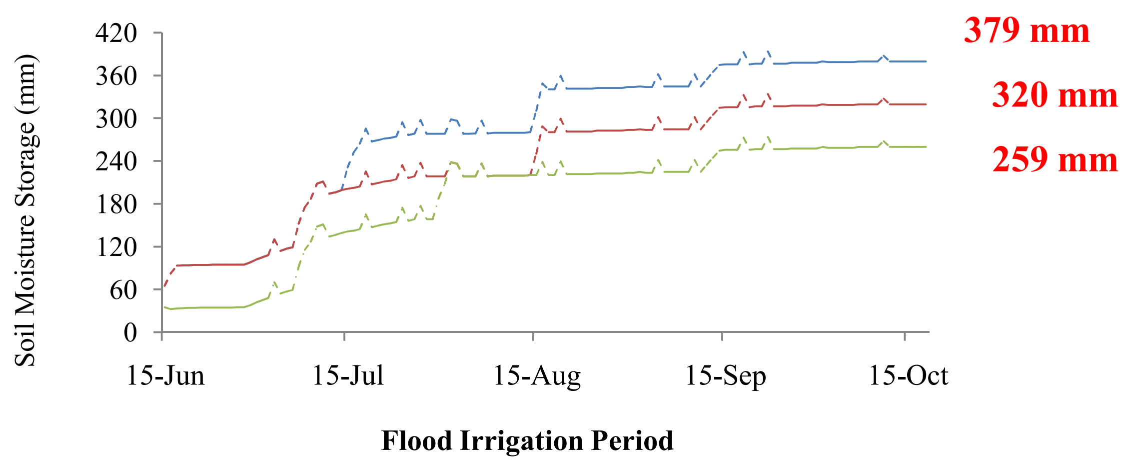


Soil Moisture Storage (SMS)

A)



C)



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Water Balance for Growth Stages

A)

Sorghum	Growth Stage	Growth Period	Days	ETo (mm d⁻¹)	*K*	ET (mm)	Soil Moisture Storage (SMS), mm	
							High-Likely Sc.	Unlikely Sc.
Short maturing cultivar	Initial	01-Jul	17	4.5	0.5	14	124	64
	Developmental	01-Aug	31	4.8	0.85	125	157	147
	Mid season	03-Sep	33	5.4	1,2	175	63	8
	Late season	27-Sep	24	6	0.9	119	32	32
	Total		**105**	-	-	**433**	**376**	**251**
Medium maturing cultivar	Initial	05-Jul	21	6.9	0.4	23	116	56
	Developmental	10-Aug	36	5.9	0.75	167	165	160
	Mid season	19-Aug	40	4.7	1.15	203	95	35
	Late season	16-Oct	28	4.0	0.80	134	15	15
	Total		**125**	-	-	**527**	**391**	**266**

>35%

>31%

C)

Sorghum	Growth Stage	Growth Period	Days	ETo (mm d⁻¹)	*K*	ET (mm)	Soil Moisture Storage, SMS (mm)	
							High-Likely Sc.	Unlikely Sc.
Short maturing cultivar	Initial	01-Jul	17	4.5	0.5	20	125	65
	Developmental	01-Aug	31	4.8	0.85	134	157	151
	Mid season	03-Sep	33	5.4	1,2	181	63	3
	Late season	27-Sep	24	6	0.9	119	34	31
	Total		**105**	-	-	**454**	**379**	**250**
Medium maturing cultivar	Initial	05-Jul	21	6.9	0.4	30	117	57
	Developmental	10-Aug	36	6,.1	0.75	175	166	164
	Mid season	19-Aug	40	4.7	1.15	211	95	35
	Late season	16-Oct	28	4.2	0.80	128	16	15
	Total		**125**	-	-	**544**	**394**	**271**

>33%

>29%

- **Both location, short maturing cultivar showed less ET & SMS**
- **Location B showed slightly higher ET & SMS compared to location A.**

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Concluding Remarks

- Clear planning in construction, with all farmers/ beneficiaries participation starting from site selection is so important .& feasible engineering design is critical for permanent structures.

- The **SAP WAT3 programme**, though based on many assumptions that simplify the reality of soil-water flow in the system , **provided reasonable values** of irrigation flood water requirement, SMS and other water balance components.

- Therefore, it can be useful as water management tool for spate irrigation technicians and probably for those **limited modelling know-how** and application experiences and/or **operating under data scarce conditions.**

- But in general further detailed studies on flood water management is crucial for efficient water use & to have a fairly flood water distribution for spate irrigation farmers.

Thank You
Dankie

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