Software demo:

Tools for planning and evaluation of drought experiments

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Framework

Review

Conceptual framework for drought phenotyping during molecular breeding

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Drought is a major threat to agricultural production and drought tolerance is a prime target for molecular approaches to crop improvement. To achieve meaningful results, these approaches must be linked with suit-

adaptive mechanisms and their genetic basis. Nonetheless, although progress has been reliable and incremental using this method [3], trait-based approaches considering drought avoidance and dehydration tolerance mechanisms

Table 1. Criteria for designing appropriate phenotyping protocols in controlled and field environments

Criterion	Appropriate protocol	Refs
Drought target		
Definition of "drought"	Define drought stress in relation to target agro-ecosystem	[11]
* climate	Rainfall distribution, evaporative demand, additional abiotic stresses such as temperature extremes	
* micro-environment	Soil water holding capacity at different depths; confounding factors associated with dry soils such as Bo toxicity, Zn deficiency, salinity, nematodes, etc.	
* crop management	Tillage systems, e.g. crop residues that help water infiltration, or plough pans that impede root penetration	
Use of appropriate check(s)	Candidate genotype(s) should be compared with agronomically elite lines and adapted to target environment in addition to experimental checks	
Design of experimental population		
Populations not confounded by phenology or other genes of major effect	Use genetic markers and phenotypic expression to design populations with minimal contrasts in phenology, height, etc.	
Populations, e.g. RILs, should avoid as far as possible agronomically inferior genotypes	Wherever possible use agronomically adapted backgrounds for developing experimental populations and avoid redundant material	[11]
T population suitable for assessing interaction with insertion position of transgene	Screen out non isomorphic (with donor background) T events while maintaining a sufficiently large population for each transgene	
Candidate trait might be linked with poor agronomic performance	Assess whether trait expression is mechanistically or physically/genetically linked to poor performance; in the former case discard	
Hypothesis testing		
Definition of "drought tolerant"	Define agronomic parameter(s) that candidate gene(s) or trait are most likely to impact on (e.g. growth rate, biomass, yield, quality, etc.)	
Consider trait expression in relation to pertinent factor(s) of yield	Frame hypotheses for candidate gene/trait effect with reference to Passioura identity (yield = WU $\times$ WUE $\times$ HI)	[9]
Measure trait at appropriate growth stage	e.g. trait might be expressed within a narrow phenological window (around anthesis for traits impacting HI)	
Consider interaction among plant organs	e.g. measurable differences in leaf water-relations traits might be pleiotropic effects of traits associated with WU such as rooting depth	
Sample appropriate tissue(s)	e.g. ABA accumulates in specific tissues such as stomata, influencing WUE	
Phenotype might be sensitive to time of sampling	e.g. down-regulation of photosynthesis typically occurs after several hours of bright sunlight/conduct phenotyping at appropriate time of day	

Model aided phenotyping

- **Before:**
  - **Target environments (GIS link)**
  - **Plan & control experiments (pre- and within season follow up): reproducibility**

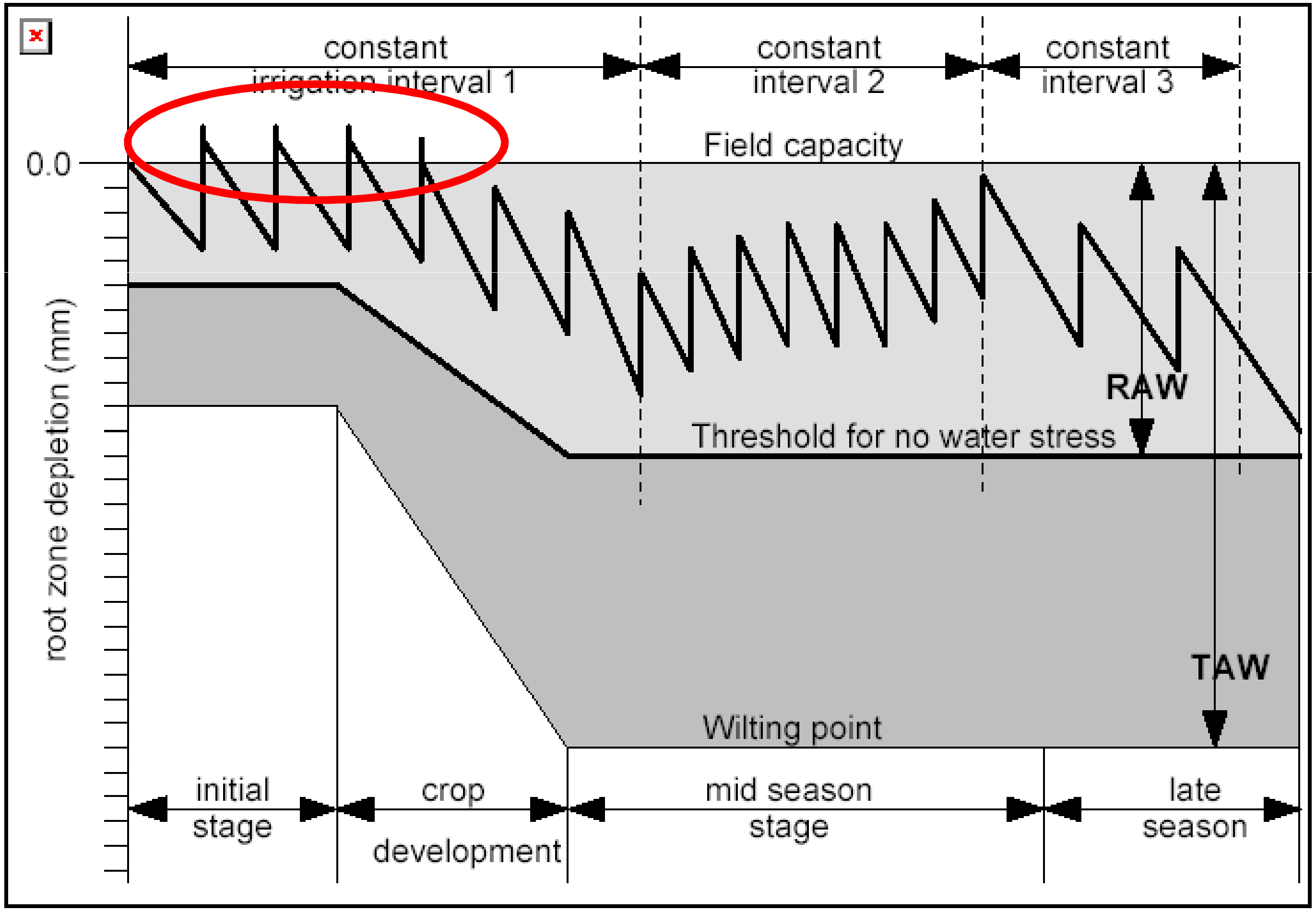
- **After:**
  - **Understand & analyze in more detail the underlying mechanisms**
  - **Refine experiments ("moderate" drought & "pre-conditioning" & repeated drought &...)**

e.g. Planning

- **Sometimes, for the most common traits, no good phenotypic clustering:**
  - **Due to lack of genotypic difference???**
  - **...or due to a lack, or lack of homogeneity or lack of control of drought intensity?**
  - **→ with the modeling tools: make sure your drought stress treatment is a proper one. (planning, control & optimization)**

e.g. Planning

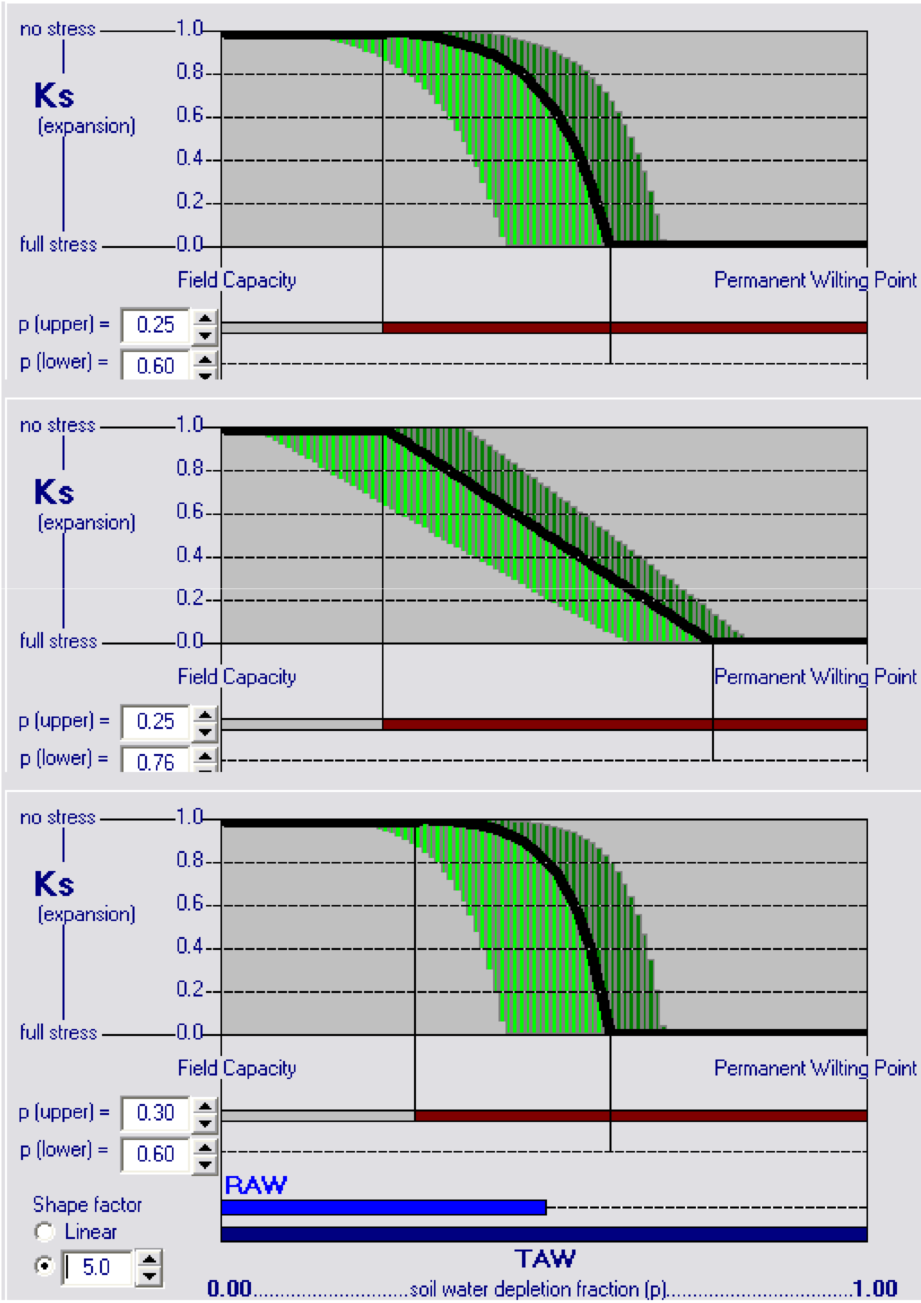
- **Over-irrigation = anaerobic conditions…**



Crop water productivity modeling: WHY?

- **Mechanisms?**
  - **Yield = WU * WUE * HI**
  - **Analyze soil water balance**
    - E (evaporation)
    - T (transpiration)
    - Runoff
    - Deep percolation
    - Δ SWC
  - **Derive types of water use efficiencies & other physiological traits:**
    - Y / water applied (irri + rain)
    - Y / ETa
    - BIO / ETa
    - BIO / Ta .... (linearity, C3, C4...)
    - Unlink temperature stress (GDD) & water stress
    - ...

“Drought” as such, does not exist



Upcoming chapter with tool-overview

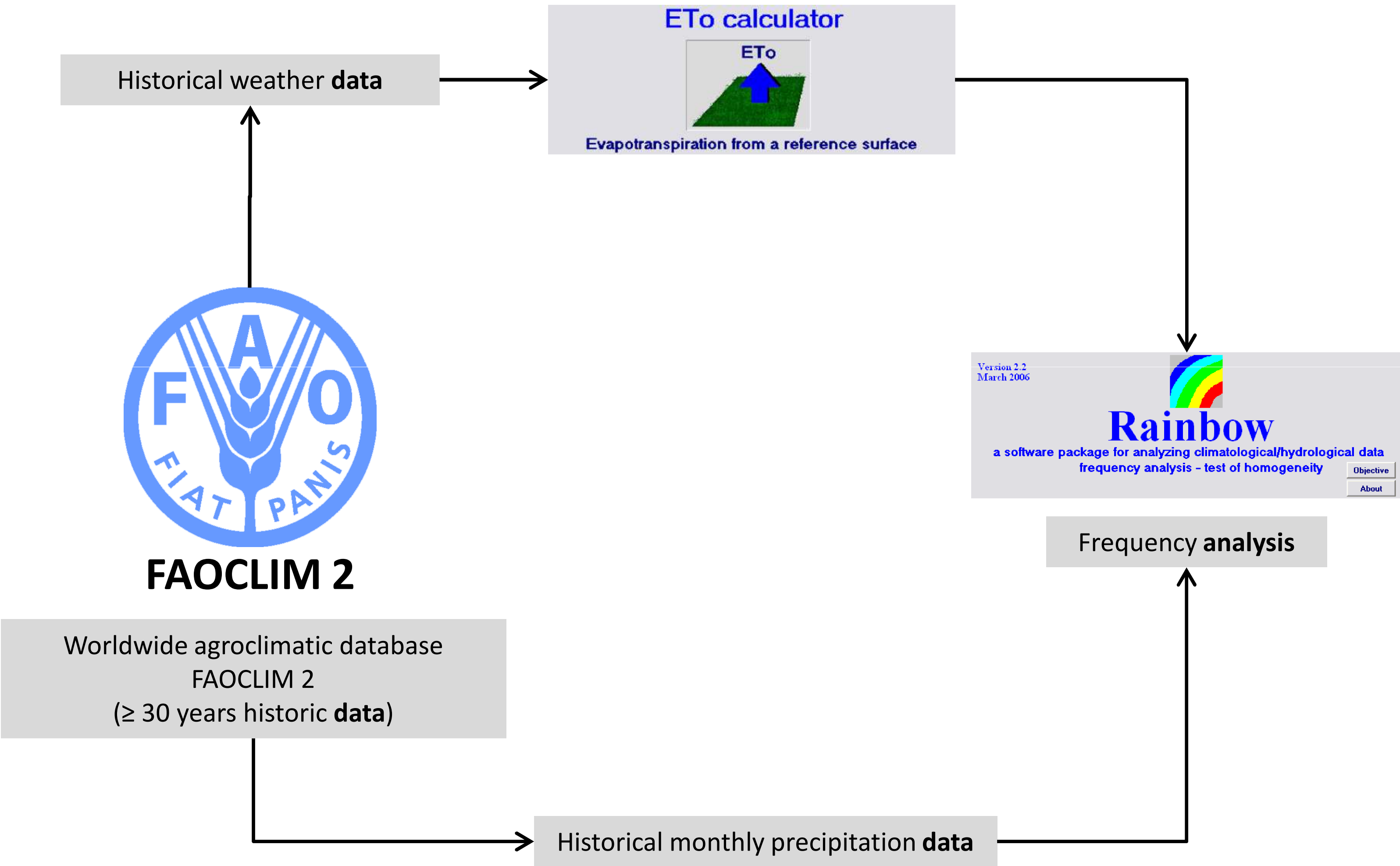
A SELECTION OF MODELS AS ASSISTANCE FOR DROUGHT PHENOTYPING

freeware

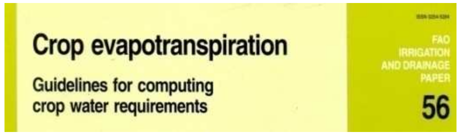
Available models: short presentation

- **EToCalc: reference evapotranspiration**
- **Agro-climatology: New Locclim 2.0 (FAO)**
- **RAINBOW: frequency analysis of climate**
- **UPFLOW: capillary rise**
- **AquaStat regional water balance tool**
- **BUDGET: soil water balance modeling**
- **AquaCrop: the new crop water productivity model of FAO**

Drought stress profiling



Drought stress profiling



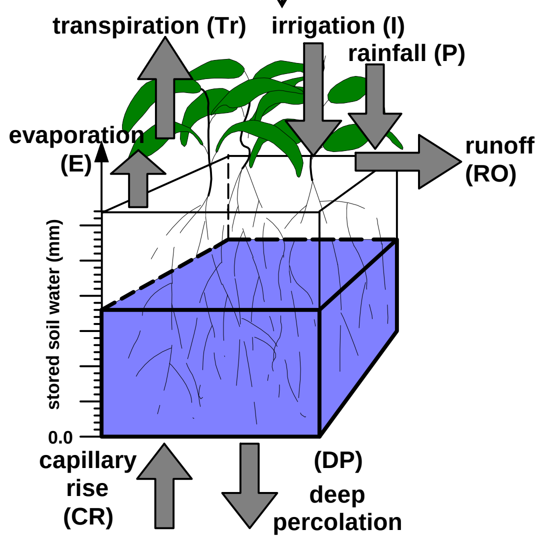
Frequency **analysis**

Wet

Normal

Dry

Weather **conditions**

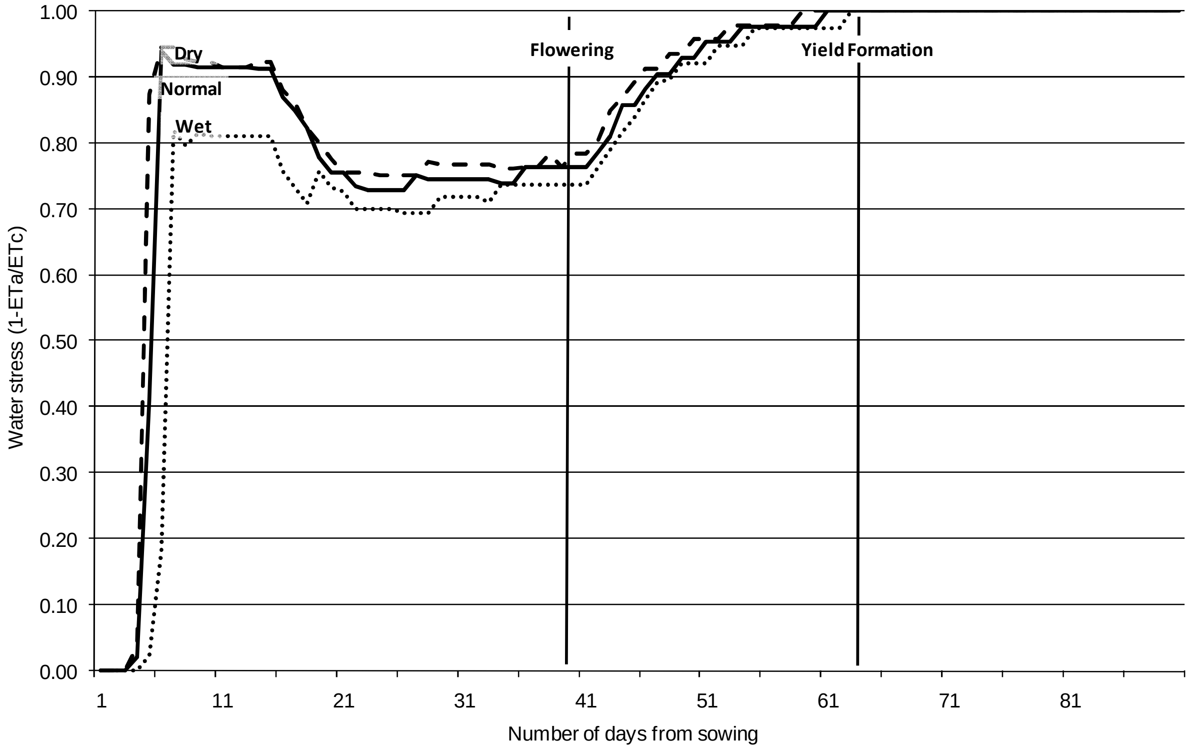


Soil water balance analysis: BUDGET

Local soil **characteristics**

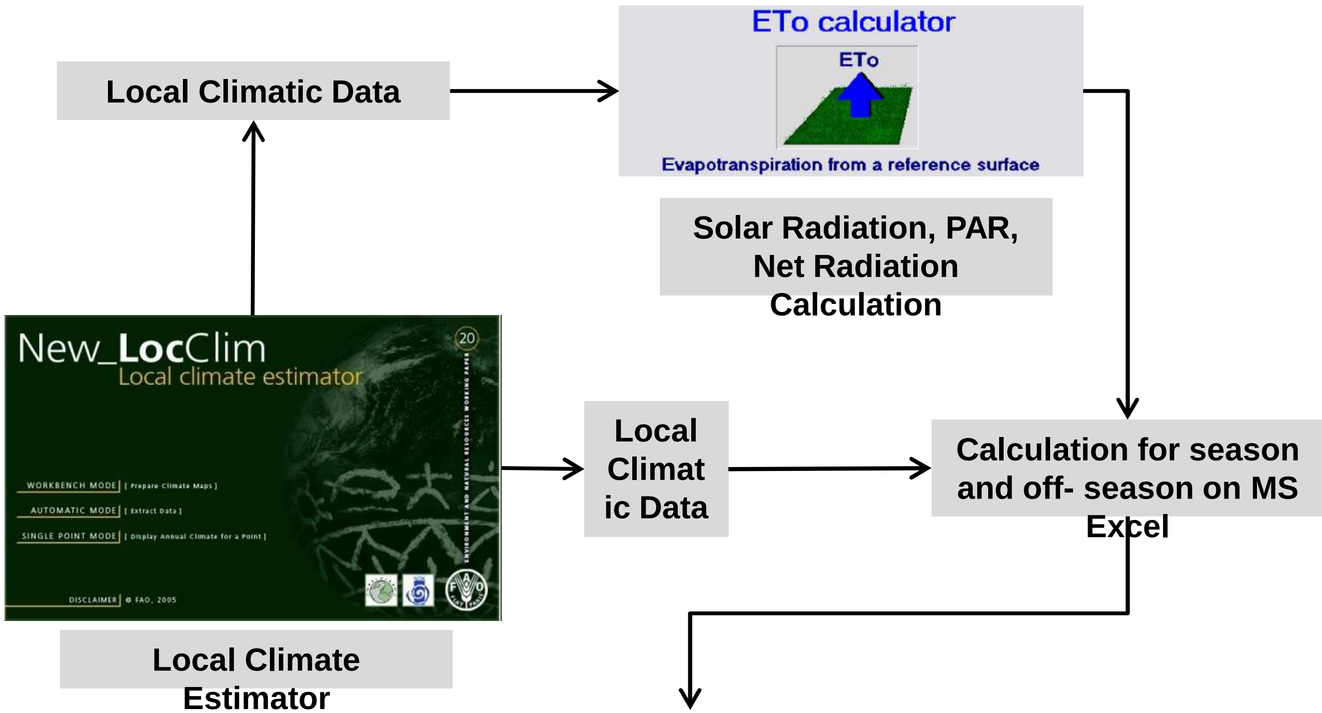
Drought stress profiling

- **Drought stress indicator = 1- ETa/ ETc**
- **Drought stress profile library developed for 9 crops in 17 sites in 3 time frames.**



Sowing date	Average water stress during			
	Initial Stage	Development stage	Middle stage	Late Stage
Off-Season A				
6-Jan	0.56	0.77	0.80	0.60
23-Dec	0.41	0.72	0.88	0.74
20-Jan	0.64	0.76	0.67	0.33
Off-Season B				
10-May	0.64	0.79	0.99	1.00
26-Apr	0.44	0.79	0.99	1.00
24-May	0.68	0.78	0.99	1.00

Rapid Agro-climatic appraisal



Indicators	Growing period	Off-growing Period
Length (days)	222	143
Rainfall (mm)	777	175
ETo (mm)	812	609
Mean Temperature (℃)	19	19
Maximum Temperature (℃)	25	28
Minimum Temperature (℃)	13	11
Solar Radiation(MJ/m²)	4328	3131
PAR(MJ/m²)	2164	1566
Net Radiation (MJ/m²)	2573	1704