OPTIONS TO REDUCE PRESSURE ON THE LIMITED WATER RESOURCES FOR AGRICULTURAL USES

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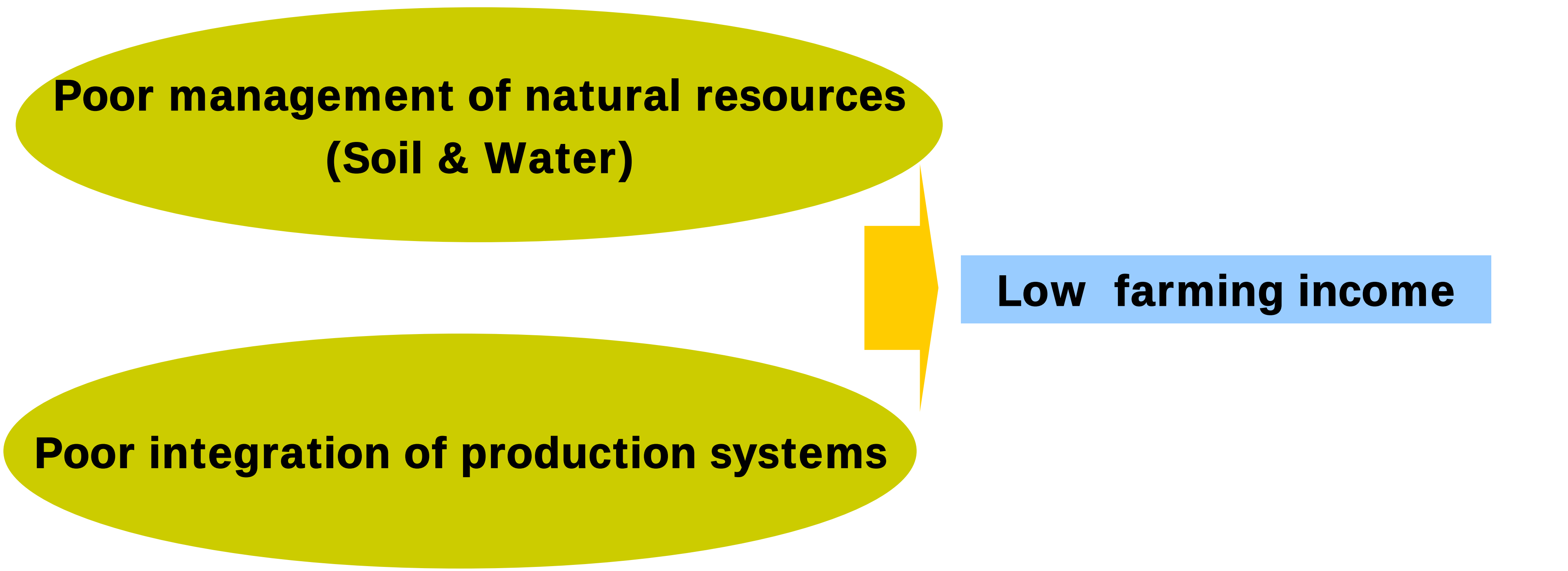
CONSTRAINTS DUE TO AGRICULTURAL DEVELOPMENT



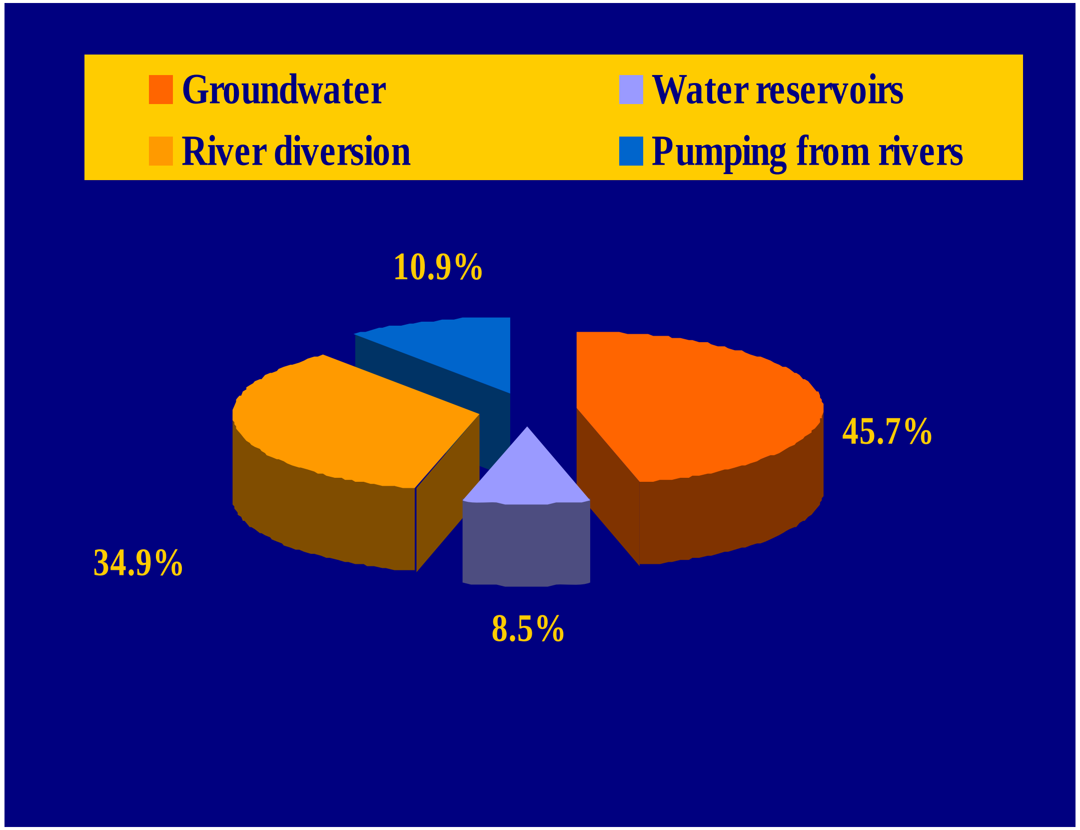
… As a fact, there was a limitation in irrigation expansion due to economic restriction

… and the consequences were:

- Informal transfer to groundwater pumping for irrigation purpose was then provided by local organizations
- Deterioration of the quality of water available to farmers
- Environmental degradation

Water sources for irrigation

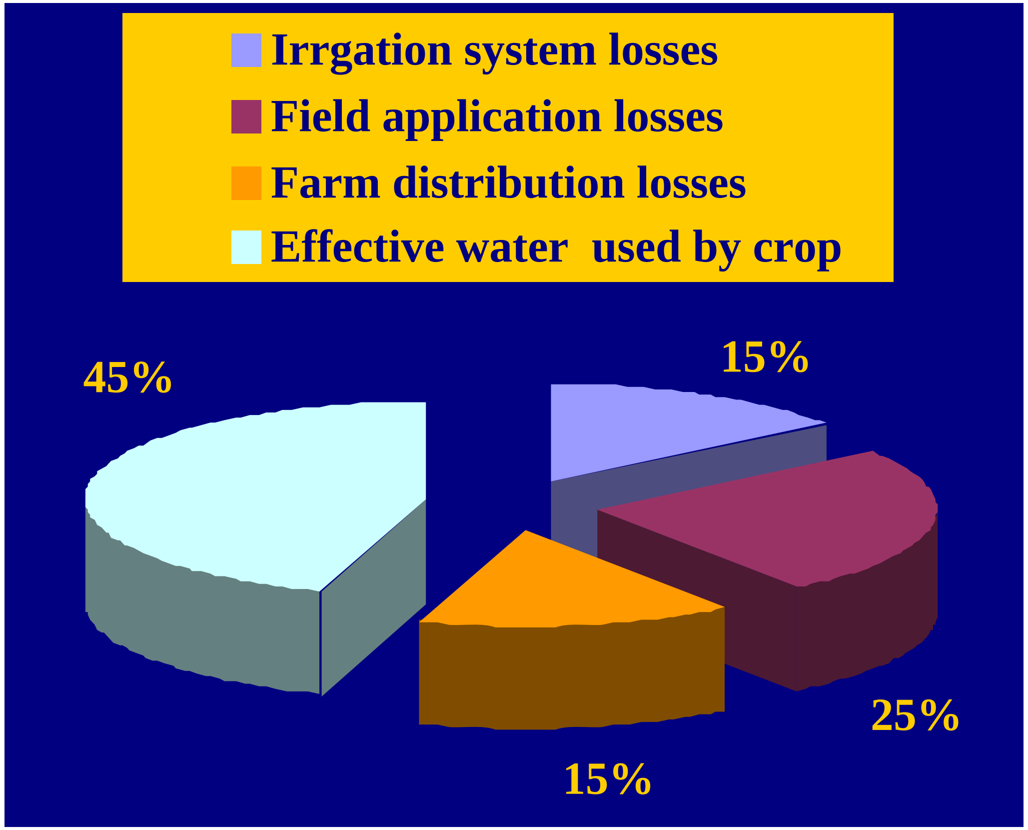
Limitation in irrigation expansion due to economic restriction has encouraged informal transfer to groundwater pumping for irrigation purpose, which resulted in a deterioration of the quality of water.



AQUASTAT, 2007

Water losses

Low irrigation efficiencies are mainly attributed to water conveyance and on-farm application, as well as to irrigation structures, often caused by inadequate operation and management of the irrigation system.



AQUASTAT, 2007

At network level

Poor conveyance systems

and canal seepage decrease the efficiency of the irrigation system

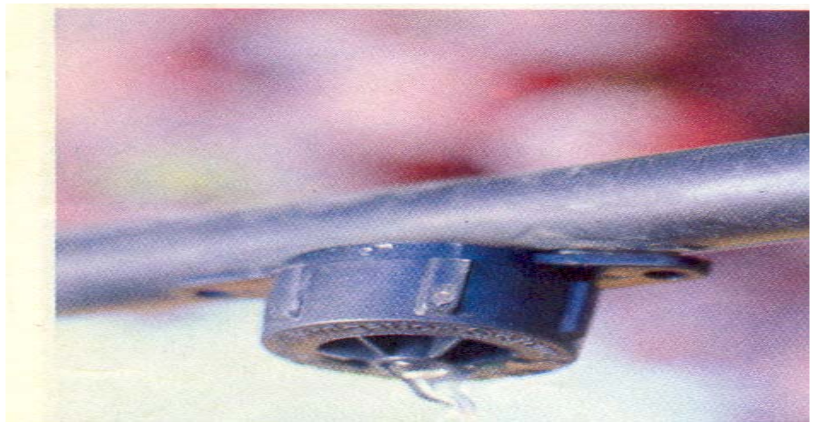
At network level

- Traditional water delivery systems are not as efficient as new delivery systems

At farm level

Traditional irrigation techniques consume huge volumes of water, where runoff, percolation and leaching are much higher compared to modern irrigation techniques.

Drip Irrigation



The concept of efficiency

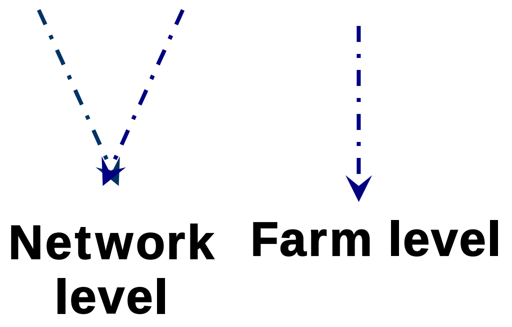
Efficiency is the ratio $\frac{\text{OUTPUT}}{\text{INPUT}}$

- **Irrigation efficiency (E_i)**
- **Agronomic water use efficiency (WUE_a)**
- **Physiological water use efficiency (WUE_p)**

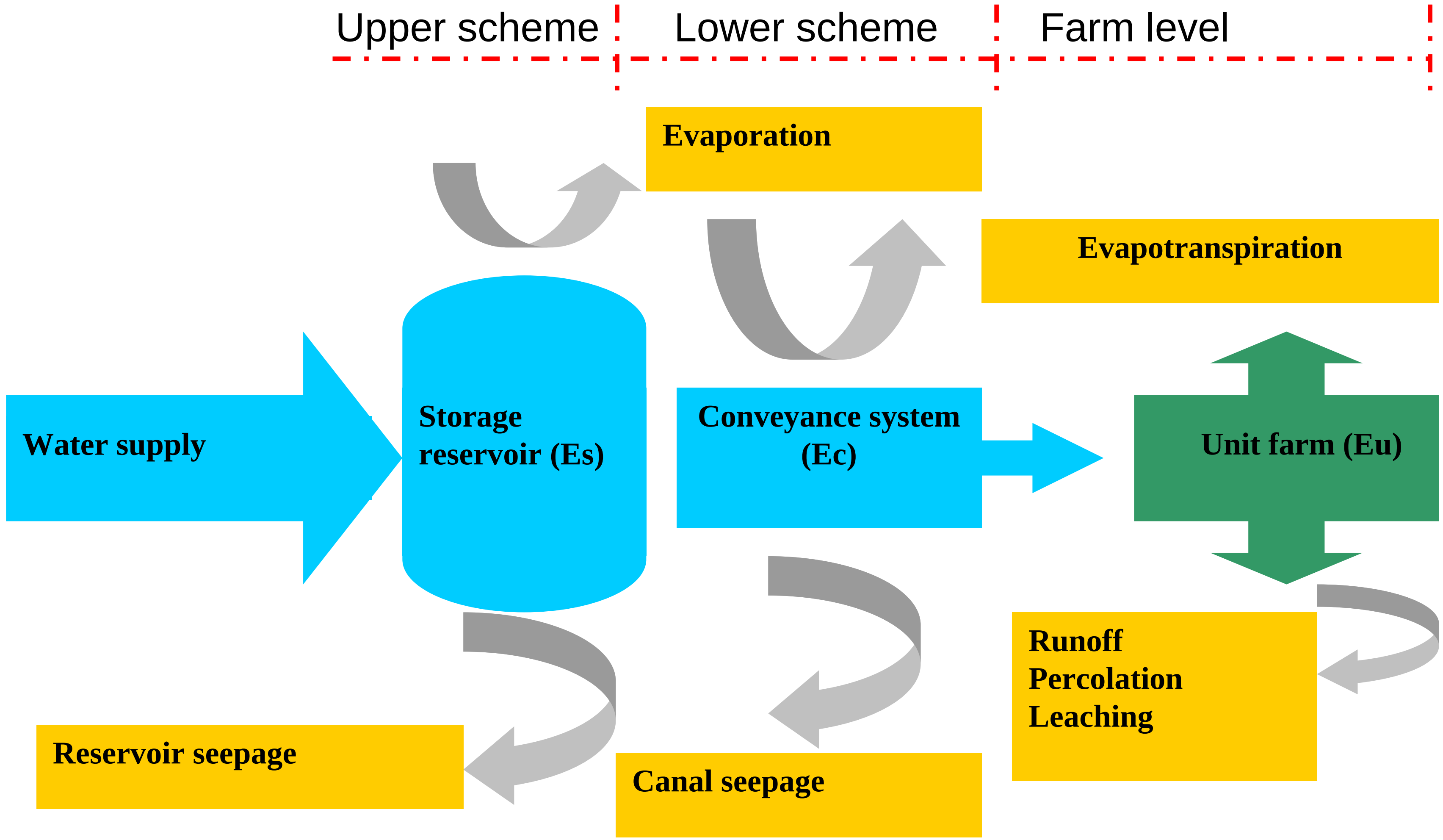
PART I: IRRIGATION EFFICIENCY

Overall efficiency of an irrigation system (E_i) is the product of reservoir storage efficiency (E_s), water conveyance efficiency (E_c) and unit farm efficiency (E_u)

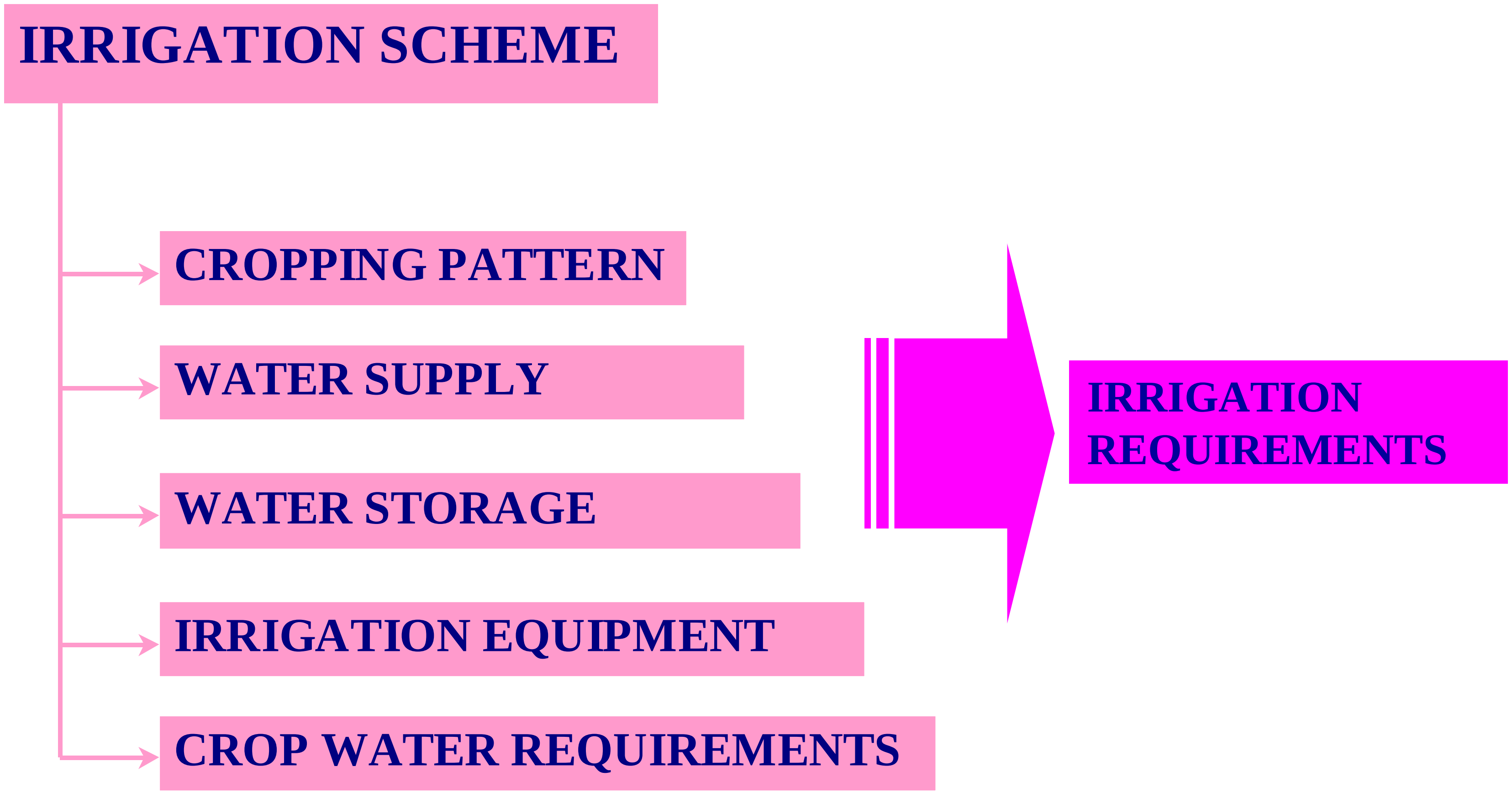
$$E_i = E_s \times E_c \times E_u \text{ (in \%)}$$



Water diversion system for irrigation



BASES FOR THE DESIGN OF AN IRRIGATION SYSTEM



UNIT FARM IRRIGATION EFFICIENCY

E_u is the ratio of the volume of water used to irrigate the farm to the volume of water delivered to the farm.

$$E_u = E_{is} \times DU$$

E_u implies:

Irrigation application efficiency

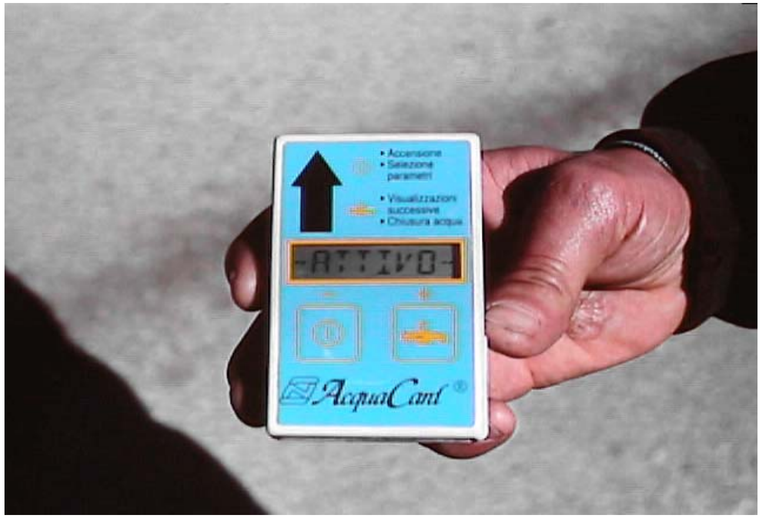
Distribution Uniformity

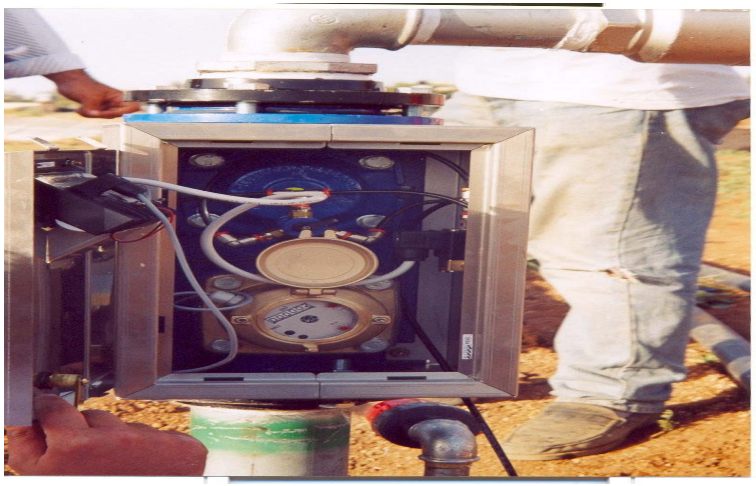
Surface irrigation systems: 40 – 50%

Sprinkler irrigation systems: 65 – 75%

Drip irrigation systems: 85 – 95%

Example: automated water distribution system





Advantages (… long term)

Appropriate irrigation technology **at network level**

- **Sustainable use of water**
- ***conservation of resources***
- ***Protection of the environment***
- ***Adequate for collective use of irrigation water***
- ***Encourage farmers to deal commonly with water uses instead of individual uses***
- **Enhancement of Irrigation Participatory Management (PIM) within the scheme**
- ***Reduce energy and other production costs***

Advantages (… short term)

Appropriate irrigation technology **at farm level**

- **Irrigation duration is operable**
- **Irrigation interval is operable**
- **Night irrigation is possible**
- **Irrigation water is calculated at priori**
- **Less irrigation water is required**
- ***Water saving option (up to 60%)***
- **Many farmers can use the same hydrant, each having his withdrawal card**

Disadvantages

- ***Initial cost is high***
- ***Require very high technical level for maintenance***

Results

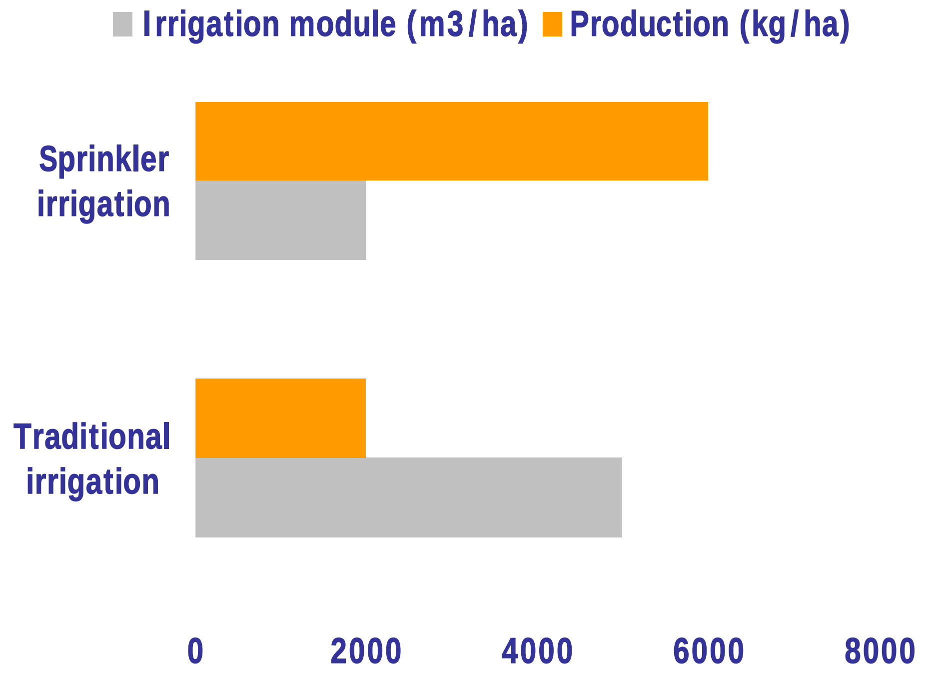
Increase of irrigated land

Increase of crop production

Increase of net farming benefit

Wheat irrigation

- **Water saving up to 60**
- **Production triples**



Rural Development Project of the Upper Bekaa Valley

Cooperazione Italiana

Conclusions (I)

- ➔ Use of modern irrigation methods, which result in less water losses
- ➔ Expansion of supplemental irrigation in rainfed farming
- ➔ Use of drought tolerant cultivars
- ➔ Produce more water with less water?

WUE - Definitions

WUE definitions			***Additions***
Physical (absolute) efficiency	**=**	**using the least possible amount of water**	**Hydrological/engineering approach: focuses on the way to divert water sources to satisfy all demand using less water**
Economic efficiency:	**=**	**derive the maximum net benefit to society**	**Economic approach: focuses on costs and values to balance supply and demand** **Economic indicators and indices of water use efficiency combine physical and economic data and also account for multi-period relationships.**
Institutional efficiency	**=**	**assess the functioning of an institution regarding water**	**Policy-related indicators of water use account for how water is used to meet social goals (ex: poverty alleviation)**
Environmental efficiency	**=**	**optimal natural resource conservation**	
Technological efficiency		**extracting more valuable products for the same amount of inputs**	

INNOVATIVE IRRIGATION

1. Agronomic: knowledge about yield response to:

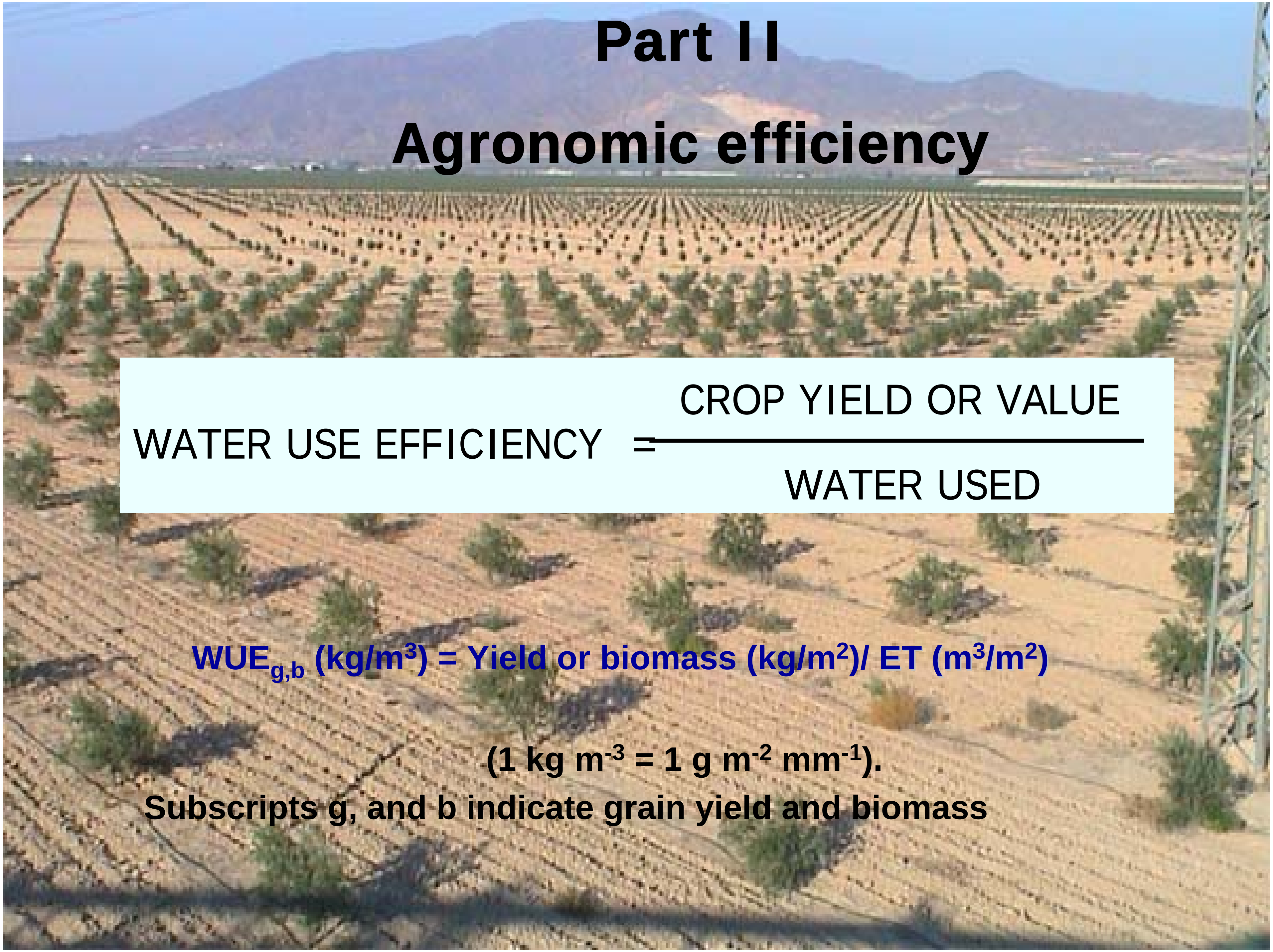
- ***a.*** **water quantity and**
- ***b.*** **quality in given conditions**

2. Technological: determining actual water needs:

- ***a. at network level***
- **b. at plot level and**

3. Economic: allocating efficiently a scarce resource.

4. Social: Providing equitable and rightful way to farmers.



Part II

Agronomic efficiency

$$\text{WATER USE EFFICIENCY} = \frac{\text{CROP YIELD OR VALUE}}{\text{WATER USED}}$$

$WUE_{g,b}$ (kg/m^3) = Yield or biomass (kg/m^2)/ ET (m^3/m^2)

(1 kg m^{-3} = 1 g m^{-2} mm^{-1}).

Subscripts g, and b indicate grain yield and biomass

RESEARCH PROGRAM

General objective

Optimization of on-farm water use efficiency by combining appropriate irrigation technologies and management practices.

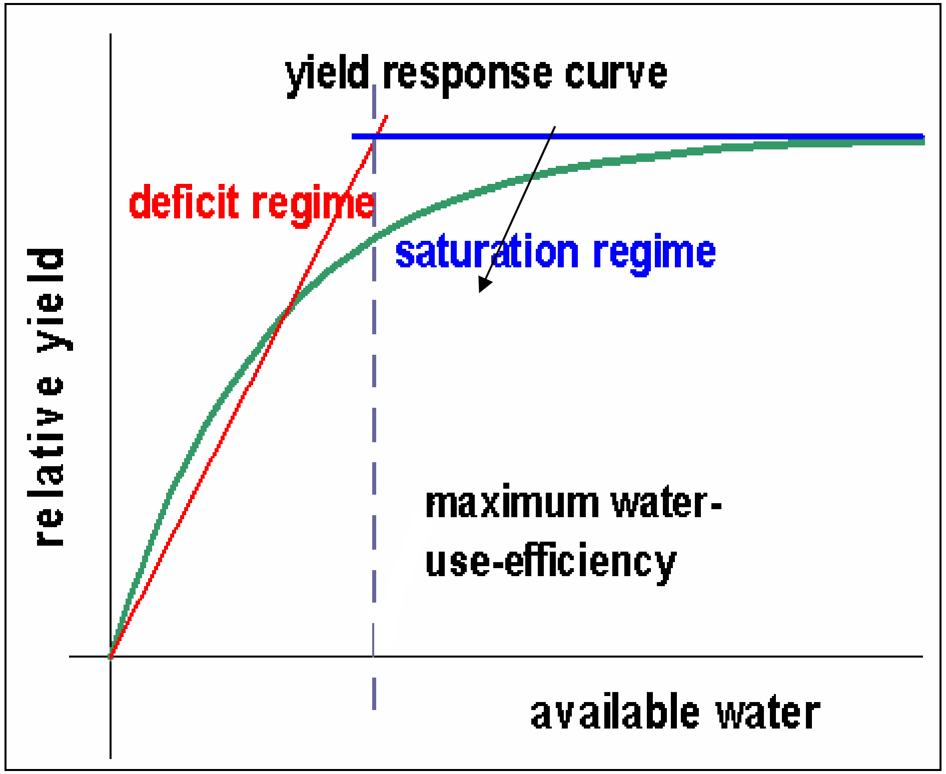
Specific objectives

- **Supporting sustainable productivity of irrigated lands;**
- **Improving water use efficiency;**
- **Increasing production levels;**
- **Providing sound irrigation information to decision-makers, water managers and end users.**

Yield response to water

Yields increase with water availability in the root zone, until a saturation level, above which there is little effect;

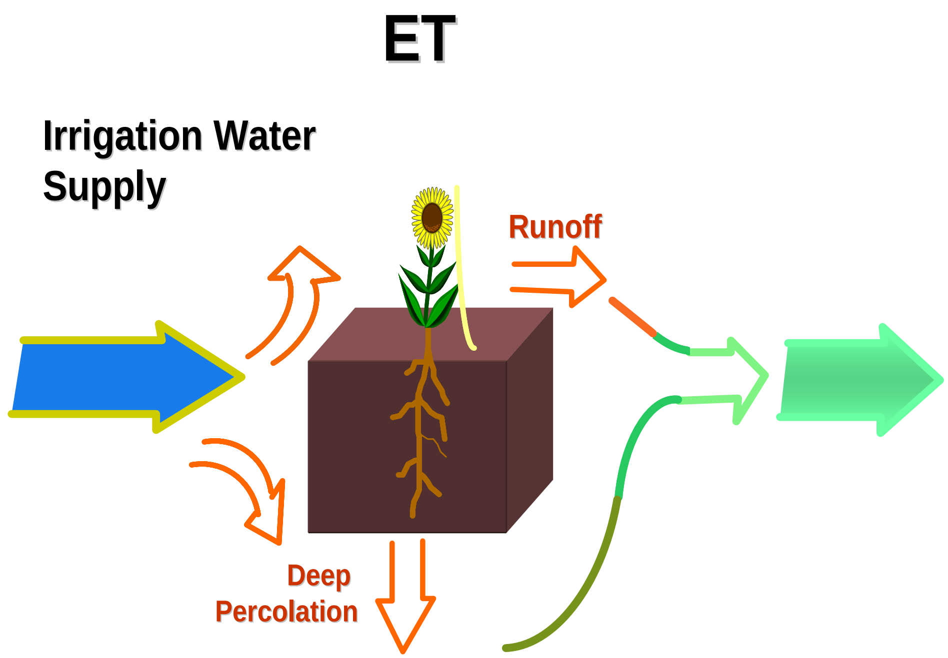
Yield response curve of specific crops depends on weather conditions and soil type as well as agricultural inputs.



Soil evaporation and plant transpiration

Soil water is primarily lost though evaporation through plants, in which case the term transpiration should be used.

Transpiration is limited by the soil moisture, as the soil dries it becomes progressively more difficult for plants to extract water.

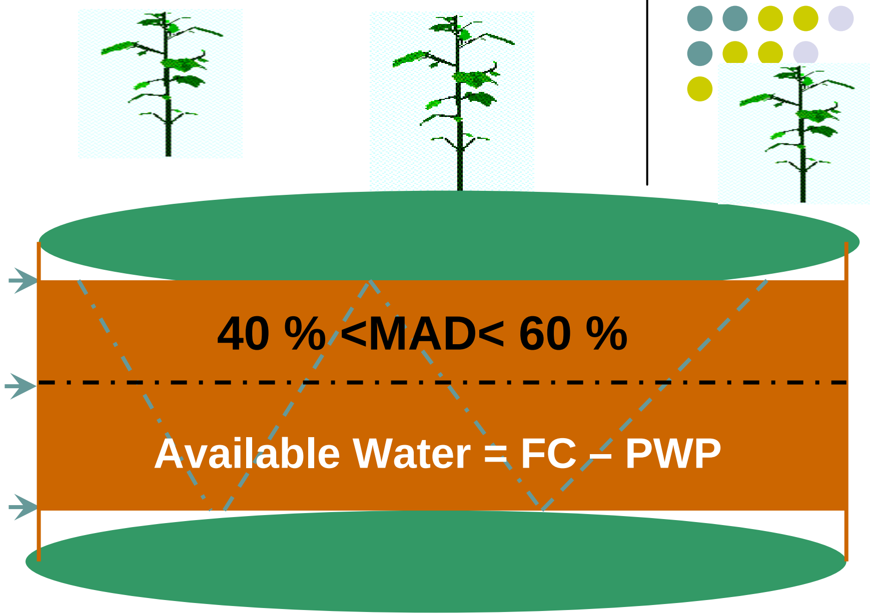


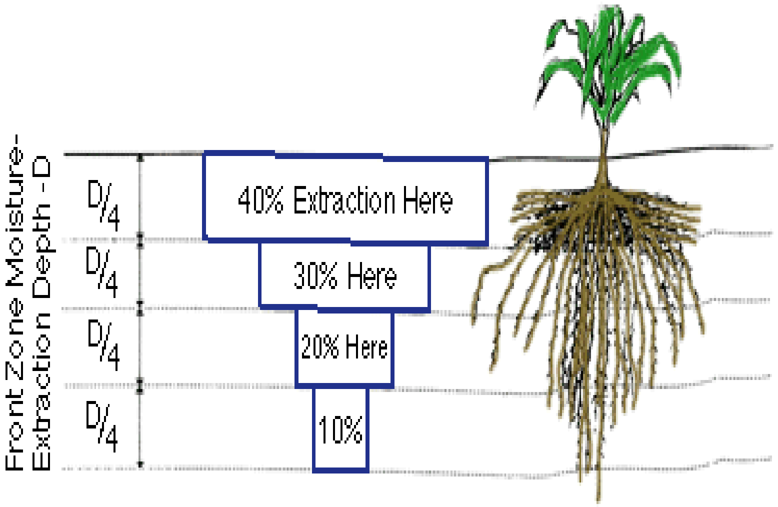
Soil Water Retention Capacity and Root Uptake

Field Capacity

Management Allowed Deficit (%)

Permanent Wilting Point (%)





Water saving approach

Develop new irrigation scheduling, not necessarily based on full crop water requirement, but one designed to ensure the optimal use of allocated water:

- **Partial Root Drying**
- **Regulated Deficit Irrigation**

Deficit Irrigation

DI or RDI is one way of maximizing water use efficiency (WUE) for higher yields per unit of irrigation water applied;

The crop is exposed to a certain level of water stress either during a particular growth period or throughout the whole growing season, without significant reduction in yields.

Objectives

- Increase WUE of a crop by eliminating irrigations that have little impact on yield.
- Yield reduction may be small compared with the benefits gained through diverting the saved water to irrigate other crops.

Weighing Lysimeter (ET_{crop})

- ET measurements (Hourly and Daily)
- Location (middle of the Exp. field)
- Area (4 × 4 m^2)
- Depth (1 m)
- Weight (22000 kg)
- Watered at 30% of SWD
- Linked to a weight indicator
- Weight loss recorded (4 times/hr; 94 readings/day)

Rye-grass drainage Lysimeters ($ET_{rye\text{-}grass}$)

- ET measurements (3-to-4 day interval)
- Location (middle of the Exp. field)
- Area ($2 \times 2\ m^2$)
- Depth (1 m)
- Watered at 30% of SWD
- $ET = I - D \pm \Delta Q$
- ($\Delta Q = 0$ when irrigation is frequent)

Weather station

Tmn, Tmx

Tdew

RHmn, RHmx

VPD

U2

Wind direction

Rg

Rain

Leaf wetness

Field experiments (1998-2008)

Maize (1998-1999)
- Karam et al., AGWAT, 2003

Soybean (2000-2001)
- Karam et al., AGWAT, 2005

Cotton (2001-2002)
- Karam et al., AGWAT, 2006

Sunflower (2003-2004)
- Karam et al., AGWAT, 2007

Lettuce (2002)
- Karam et al., Journal of Applied Horticulture, 2002

Potatoes (2000-2005)
- Karam et al., Acta Horticulturae, 2005
- Karam et al., Journal of Agronomy, 2009

Sweet Pepper (2005)
- Karam et al., European journal of horticultural science, 2009

Eggplants (2008-2009)
- Karam et al., European journal of horticultural science (under preparation)

Working hypothesis

The relationship between yield and ET is an appropriate framework to investigate the pattern of WUE

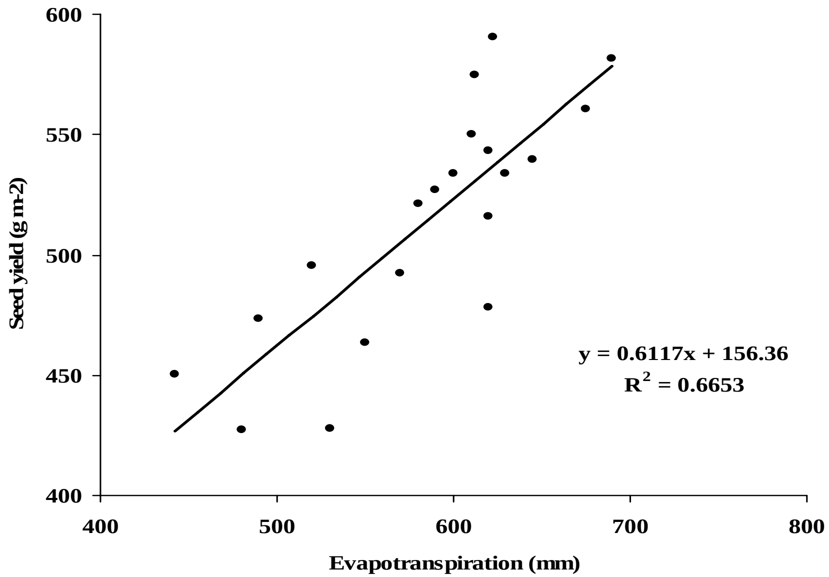
Linear models were fitted to the data:

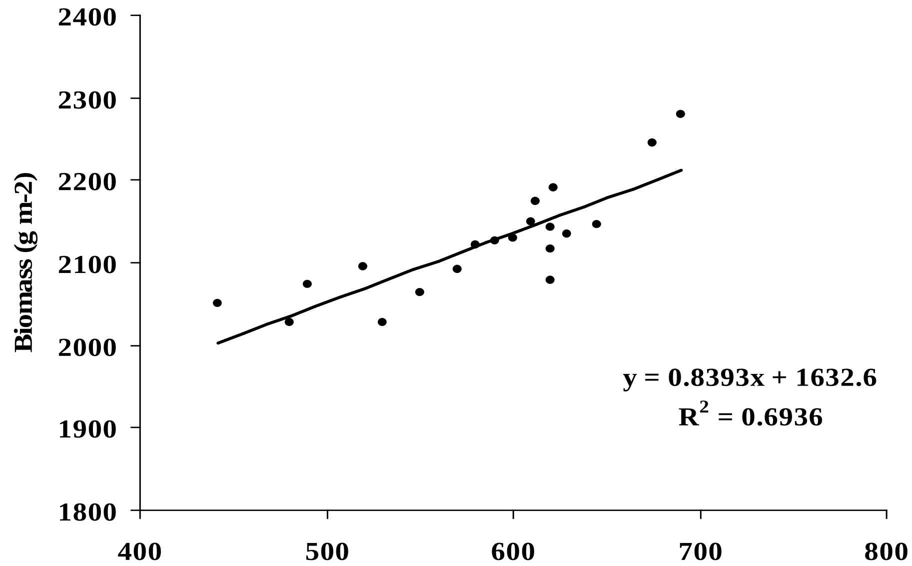
$$Y = a_1 (ET) + b_1$$

$$B = a_2 (ET) + b_2$$

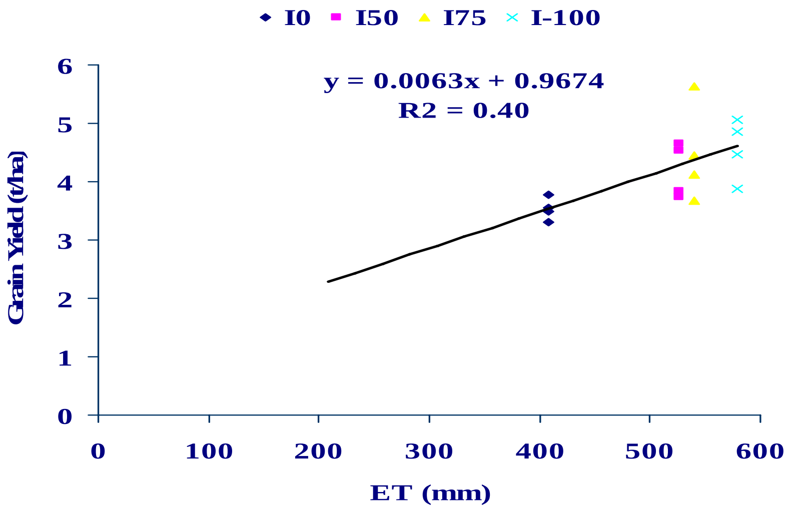
$$(WUE = Y\ ET^{-1}\ ;\ WUE = B\ ET^{-1})$$

Sunflower (2003-2004) & Wheat (2000-2004)

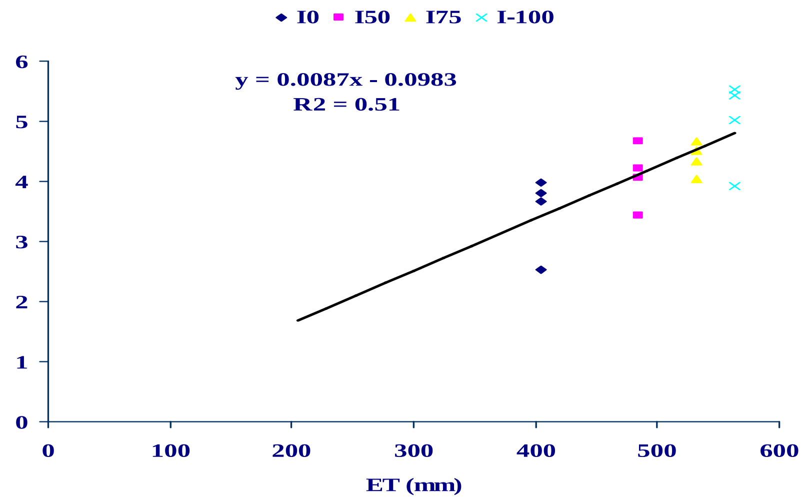




Waha



Hourani



(Data points are means of five quadrates of 1m² each per treatment)

Results are a kind of database for the irrigated crops

- Corn seasonal ET reached on the lysimeter 952 mm in 1998 and 920 mm in 1999. Grain-related water use efficiency (WUE_g) varied in corn treatments from 1.34 to 1.88 kg m^{-3}, while at biomass-basis (WUE_b) the values varied from 2.34 to 3.23 kg m^{-3}.
- Soybean seasonal ET totaled 800 mm in 2000 and 725 mm in 2001. Seed-related water use efficiency of soybean (WUE_s) varied from 0.47 to 0.54 kg m^{-3}, while WUE_b varied from 1.06 to 1.16 kg m^{-3}.
- Cotton, seasonal ET was 641.5 mm in 2001 and 669.0 mm in 2002. Average WUE_l values varied among treatments from 0.43 to 0.64 kg m^{-3}, while WUE_b varied from 1.82 to 2.16 kg m^{-3}.
- Sunflower, average across years of evapotranspiration attained 672 mm. WUE_s of sunflower varied among treatments from 0.76 to 0.87 kg m^{-3}, while at biomass-basis WUE_b varied from 3.46 to 4.1 kg m^{-3}.

Data from local experiments are used in model simulation

Example of applications

AquaCrop (FAO, 2009)

MOPECO (UCLM, Spain, 2009)

Farm Level Optimal Water management Assistant for Irrigation under Deficit (FLOW-AID)

Work Package 6: Lebanon Test Site

Lebanese Agricultural Research Institute (LARI)

WP6: Objectives

- Field testing, adaptation and demonstration of the DSS, irrigation controller and dielectric tensiometers under local circumstances to deal with scarcity in view of diversity in irrigation technology;
- **Analyze potential water saving by applying state-of-the-art irrigation techniques at field level;**
- Identification and quantification of water use in different deficit irrigation programs, assessment of water use efficiency;
- Increase awareness through involvement of local stakeholders.

GP1 Smart Irrigation Monitor

***S**mart **W**ater **A**pplication **T**echnology*

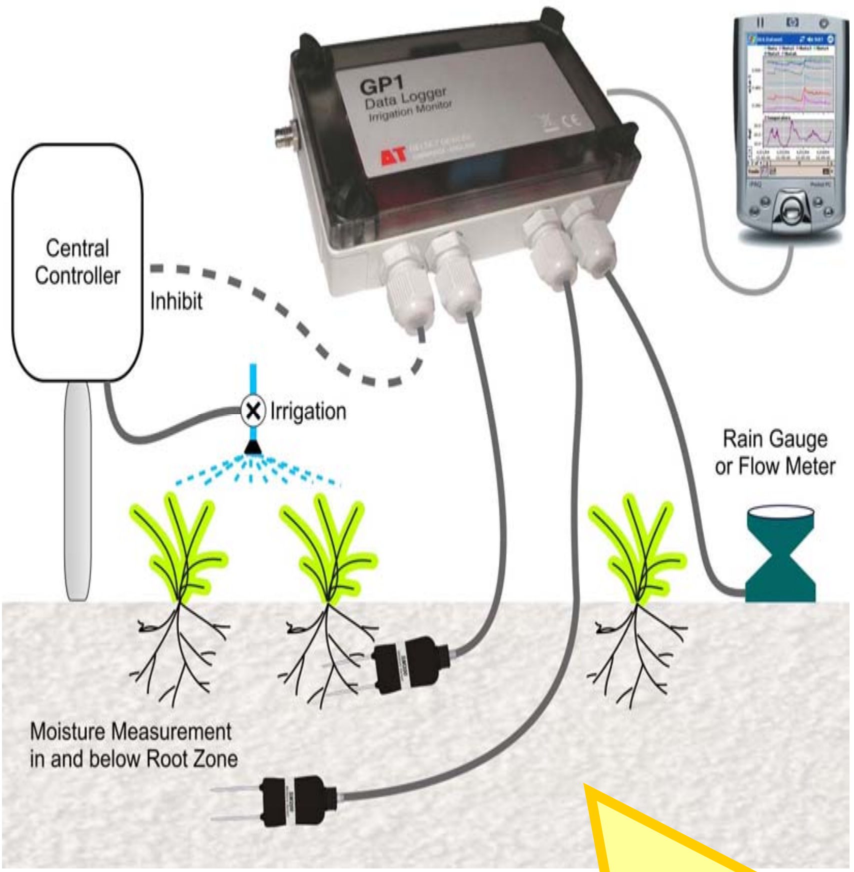
Intelligent Irrigation based on:

- Soil moisture
- Rainfall (optional)
- Temperature
- Soil absorption dynamics

Benefits are:

- Minimize water run-off
- Minimize percolation losses
- Enhance crop quality

The GP1 Irrigation Monitor provides a number of unique features to improve irrigation efficiency, crop quality, and implement intelligent irrigation.



Example: Irrigate when SMC < 30%
Inhibit irrigation when SMC > 40%
Or Rainfall > 4 mm/h

GP1 Smart Irrigation Monitor

SM200 Soil Moisture Sensor is the ideal partner for the GP1.

Having research grade performance:

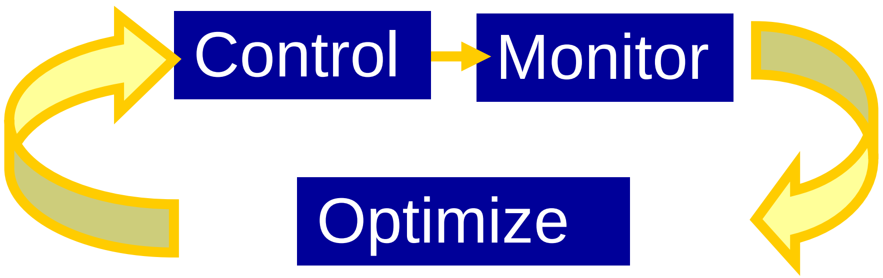
- Give reliable readings in all soil types
- Allow easy installation in soils at depth
- Works in saline soil conditions and at extreme temperatures
- Allow free irrigation monitoring and control.

Example: Irrigate when SMC < 30%
Inhibit irrigation when SMC > 40%
Or Rainfall > 4 mm/h

GP1 Irrigation Monitoring Features

A powerful irrigation tool needed to:

- Implement intelligent irrigation control
- Monitor processes
- Optimize irrigation
- Minimize water run-off and percolation losses
- A controller for precision irrigation
- Monitor excess irrigation.



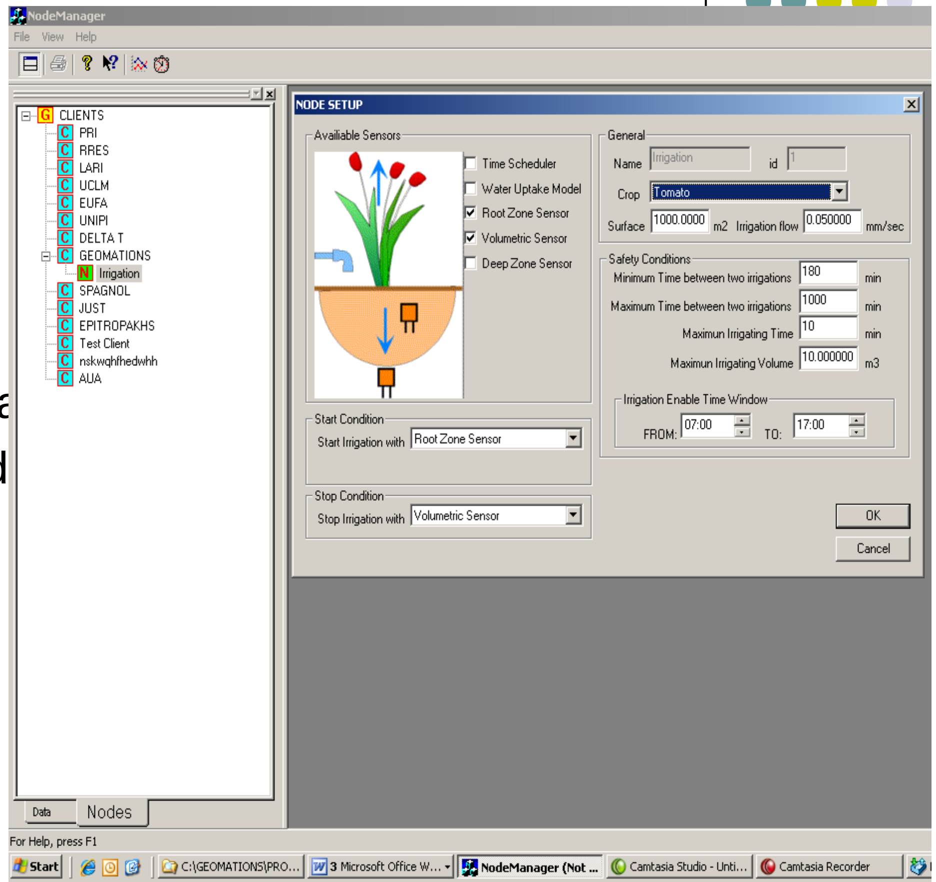
Real-time irrigation control

Storage of soil data

Allows SWAT (Smart Water Application Technology) intelligence to be added to a central controller.

Decision Support System (DSS-GP1 Coupling)

- Crop: Eggplants
- Surface: 5000 m2
- Volumetric Sensor (SM200)
- Irrigation flow: 0.005 mm/sec
- Minimum time between two irrigations: 2 da
- Maximum time between two irrigations: 4 d
- Maximum irrigation time: 4 hours
- Maximum irrigation volume: 340 m3
  - (based upon 40% soil water deficit)



Field installation to serve as test site for initial calibration of GP1

- Installation: Early June 2008
- 1st electronic data sets: Late June 2008
- Plant material: Eggplants
- Watering regime
  - Control irrigated at field capacity with no irrigation restriction
  - WS1 treatment irrigated at field capacity with irrigation restriction prior to flowering
  - WS2 treatment irrigated at field capacity with irrigation restriction at flowering
  - WS3 treatment irrigated at field capacity with irrigation restriction after flowering onset

- Nitrogen fertilization
  - 1st split at early growth stage as NH4NO3
  - 2nd spilt at fruit bulking as KNO3

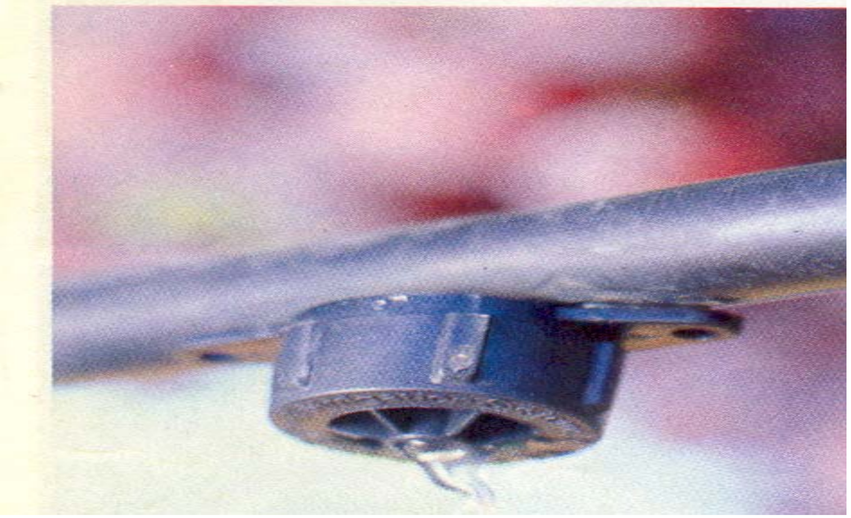
- Cultivated area: 60 m NS × 36 m WE
- Irrigation system: drip irrigation (4 l/hr)
- Demonstration activities: DIAM-LARI Technical Staff, under-graduate students.

- GP1s were placed in the field into metallic boxes to avoid any kind of mechanical harming or vandalism

Irrigation system

- Drip irrigated field
- Pressure at the head pumping unit: 4.0 bars
- Pressure at the hydrant: 3.5 bars
- Pressure at manifold: 1.0 bar
- Flow meter
- Flow limiter (5 l/s)
- Filtration unit (sand + disc filters)
- Fertigation tank of 300 l capacity
- Online drip system
- Unit flow: 4 l/hr
- Dripper spacing along the line: 40 cm
- Space interline: 1m

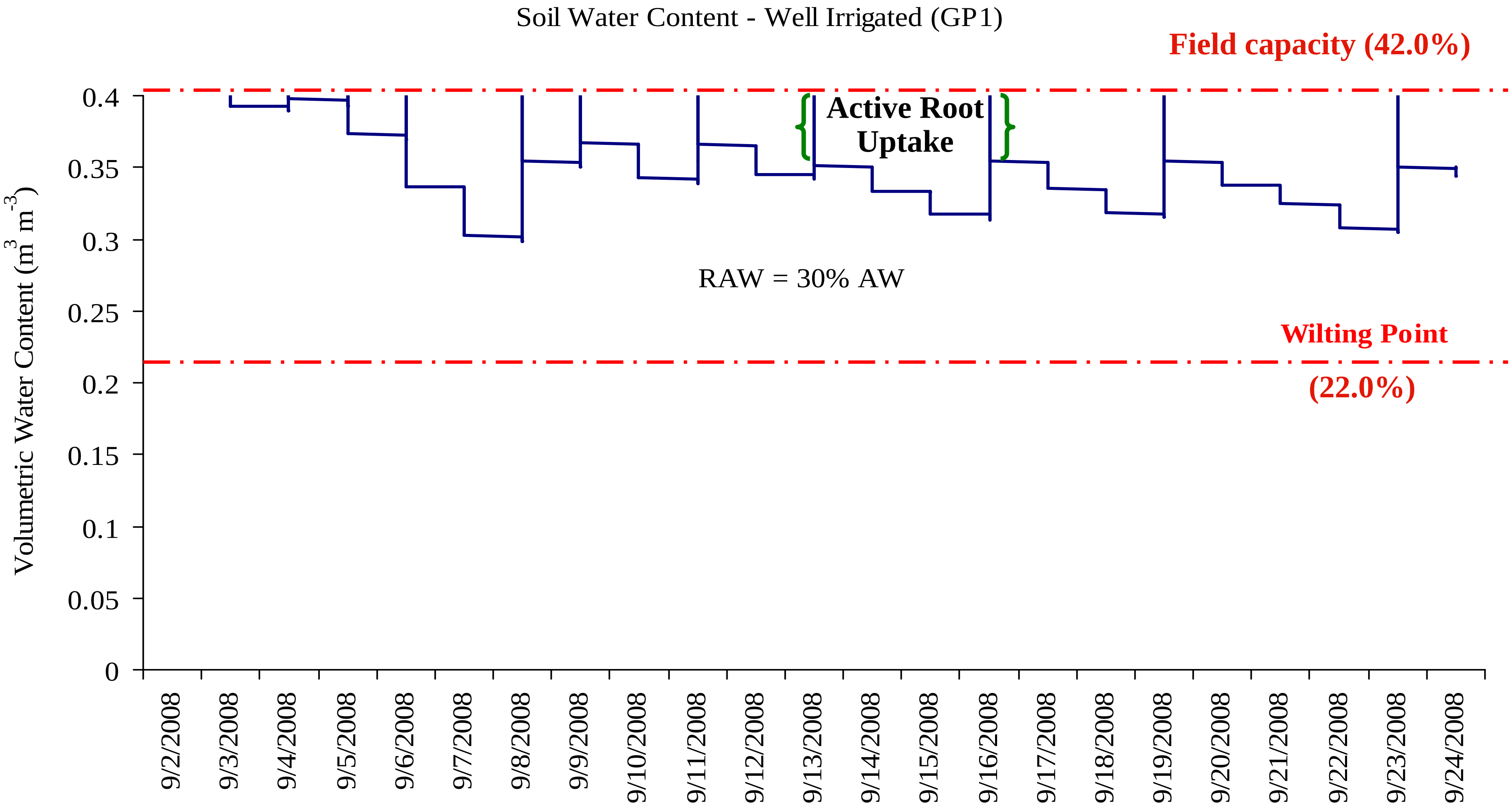
Drip Irrigation



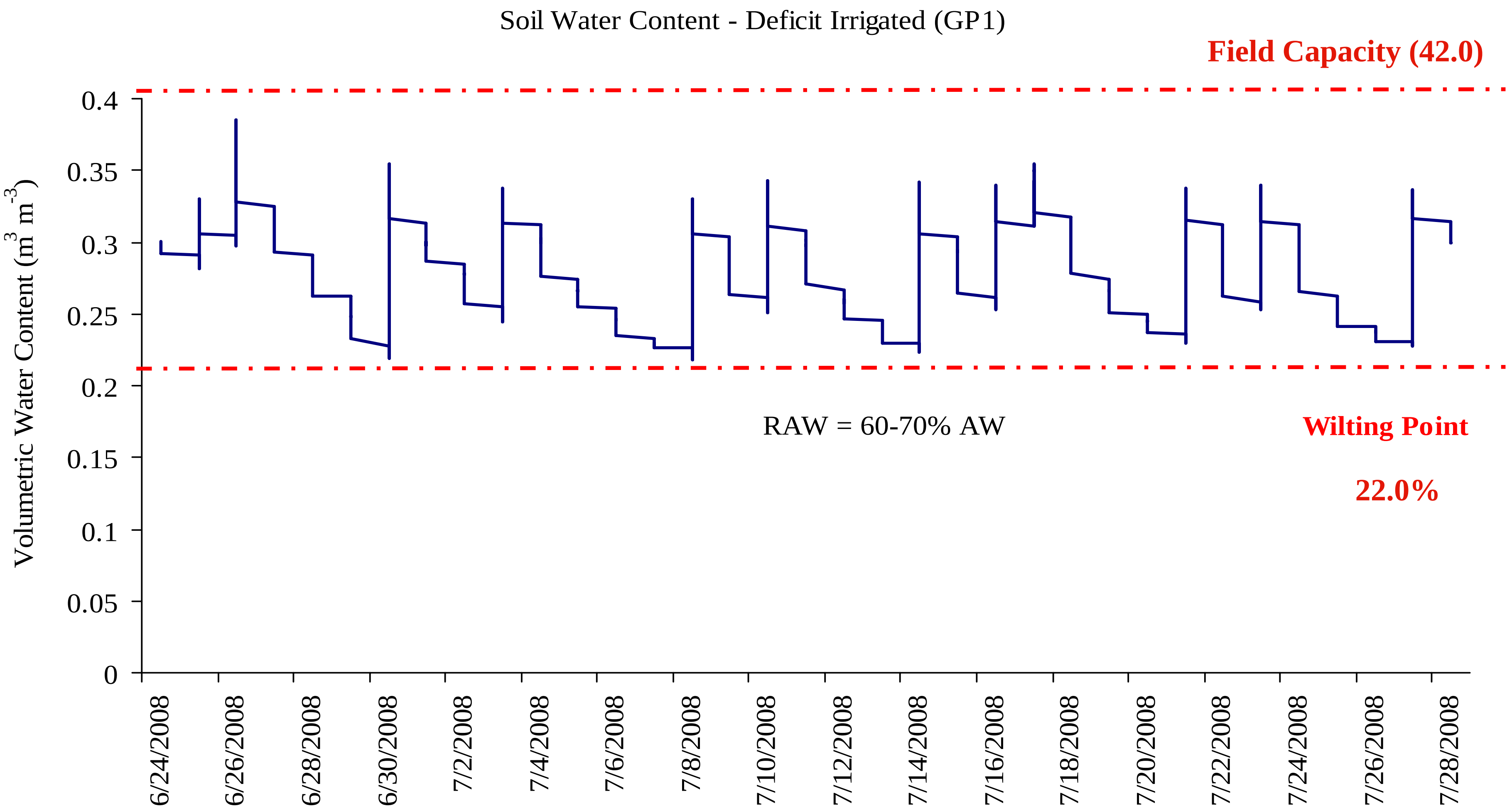
Irrigation treatments

- WS1: treatment irrigated at 100% of FC with no irrigation prior to flowering for two-week interval;
- WS2: treatment irrigated at 100% of FC with no irrigation at flowering for two-week interval;
- WS3: treatment irrigated at 100% of FC with no irrigation after flowering onset for two-week interval;
- A control (C) was designed to receive a full irrigation at 100% of field capacity with no water restriction.

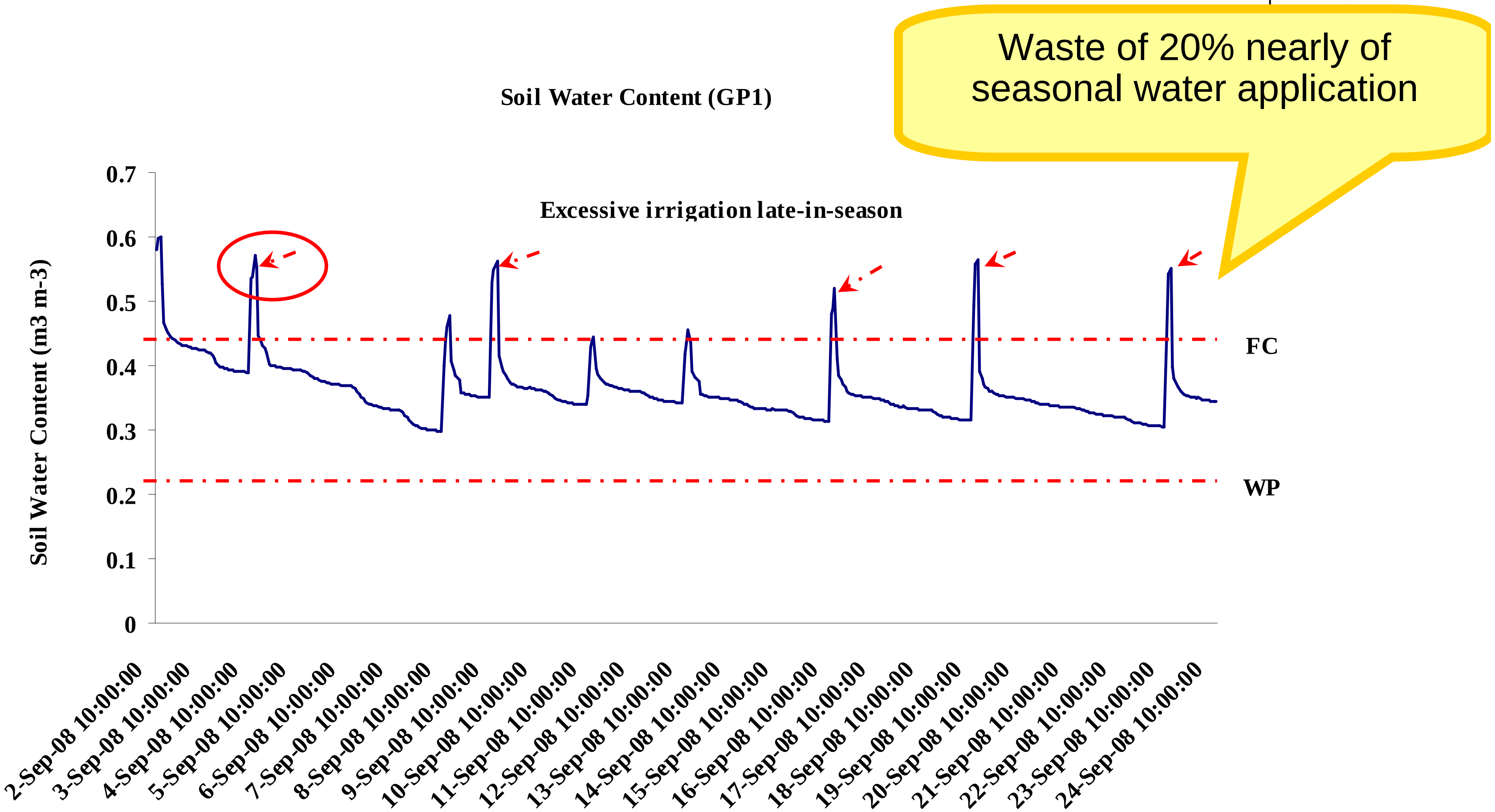
In-depth analysis



In-depth analysis

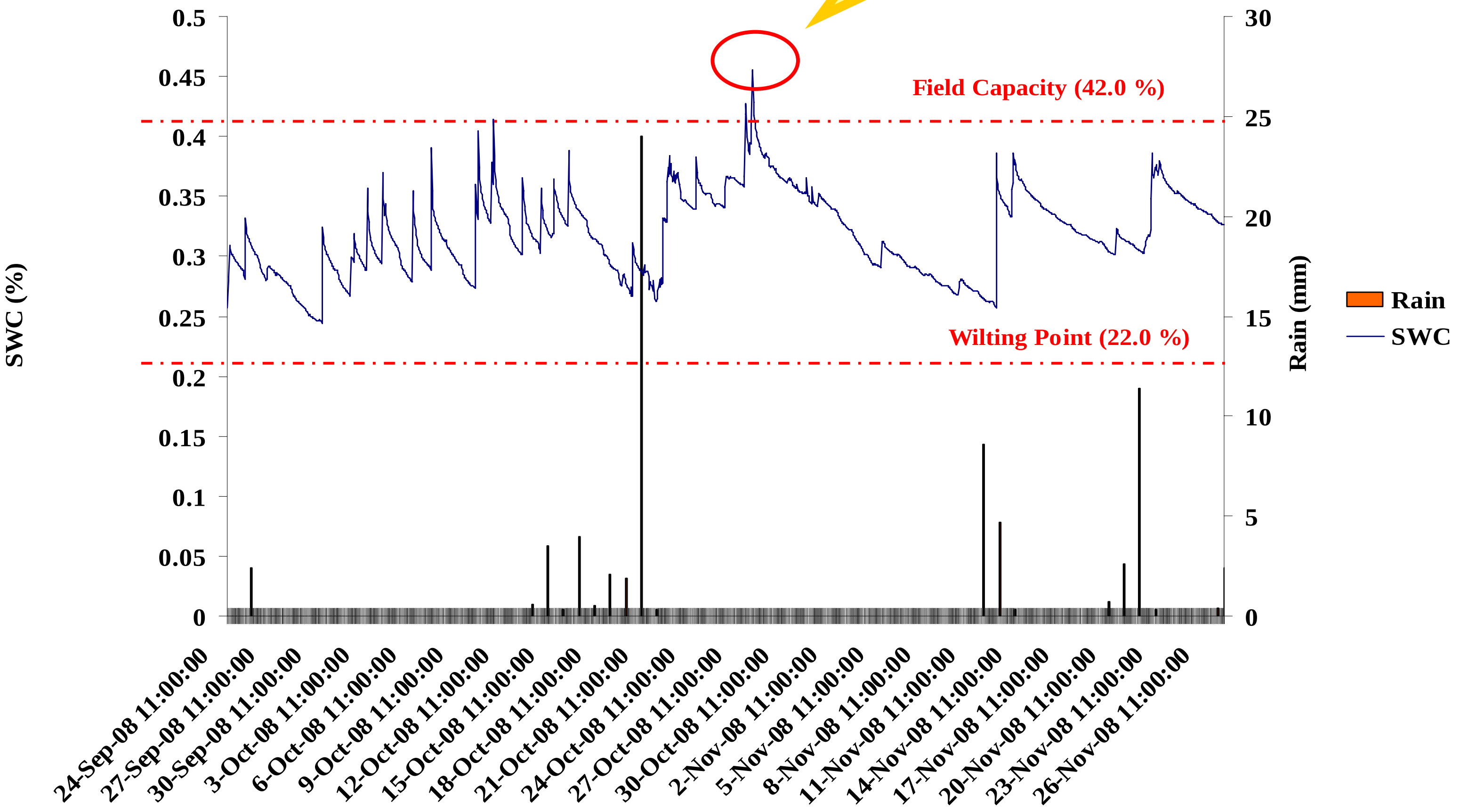


In-depth analysis

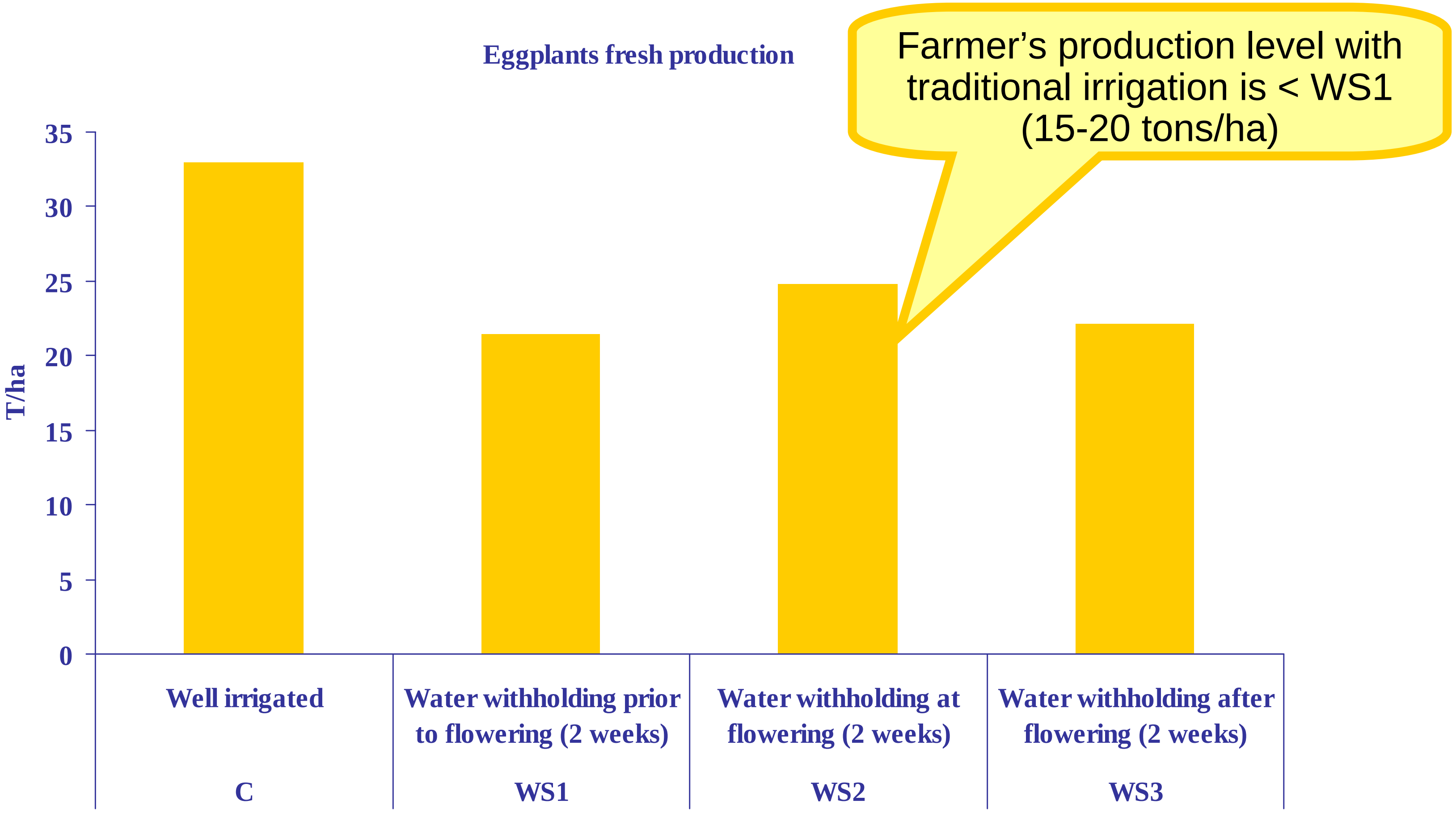


In-depth analysis

Indicator for extreme rainfall during winter time



Eggplants Fresh Production



Conclusions

- Reliable communication over years
- High security of data
- Easy access through friendly interface platform
- Remote access with password from any place in the world
- Cost effective
- Flexible solutions and programming tools for integrators and researchers available