# Effects of water harvesting techniques on soil properties and water management (with focus on Tunisia)

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ITALIAN AGENCY FOR DEVELOPMENT COOPERATION

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- Basic principles of WH and classification of WH types
- Case applications and issues
  - *Crop production*
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  - *Groundwater recharge*
  - *Drinking/Watering*
  - *Flood spreading / prevention*
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  - *Combined effects*
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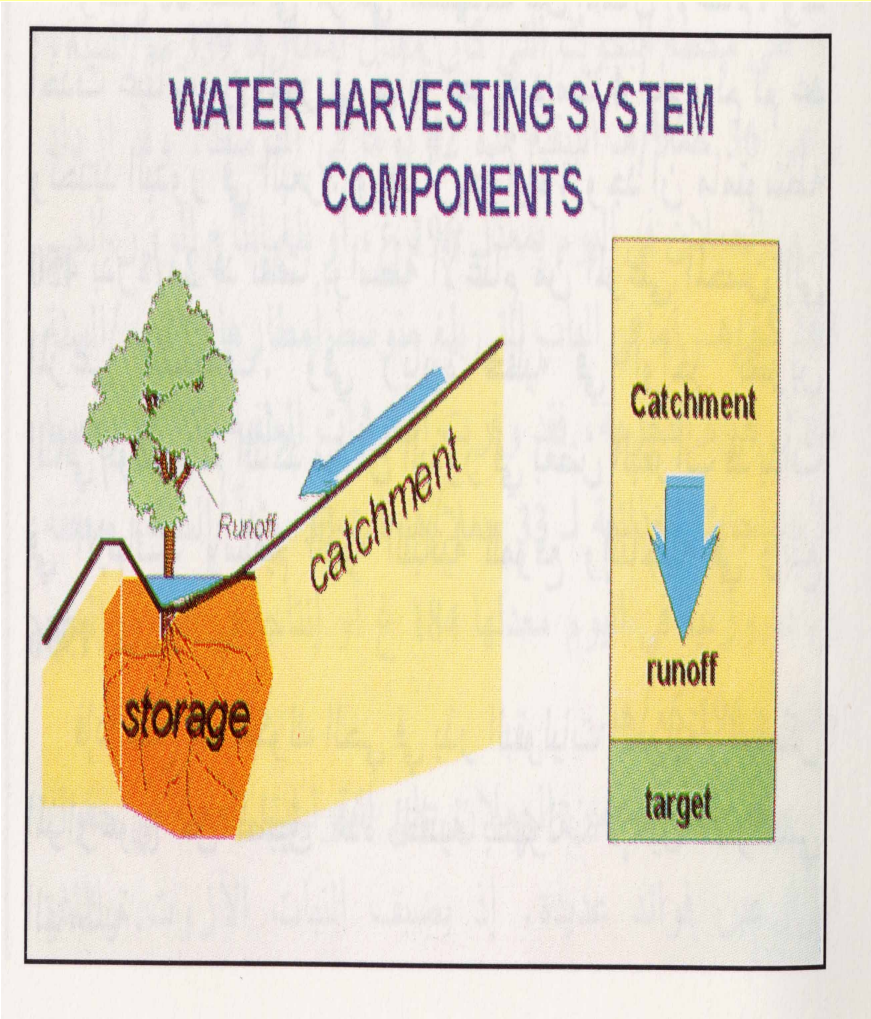
# Introduction

The dry areas are characterized by:

- rainfall is rare, variable and torrential
  - Insufficient to meet the basic needs for crop production,
  - Poorly distributed over the growing season ➡ risky farming
  - Runoff can cause erosion and be lost later by evaporation from swamps ‘salt sinks”,
- High temperature ➡evapotranspiration
- Shallow and poor soils ➡ degradation, moisture stress ➡desertification
- Dominating rainfed agriculture
- An increasing competition (drinking, industry, tourism, agriculture, etc.) vis-à-vis the water resources

# BASIC PRINCIPLE & CLASSIFICATION

*Depriving part of the land of its share of rain, which is usually small and non productive, and adding it to the share of another part in order to bring the available water amount closer to the water requirements of crops (Oweis et al., 2001)*

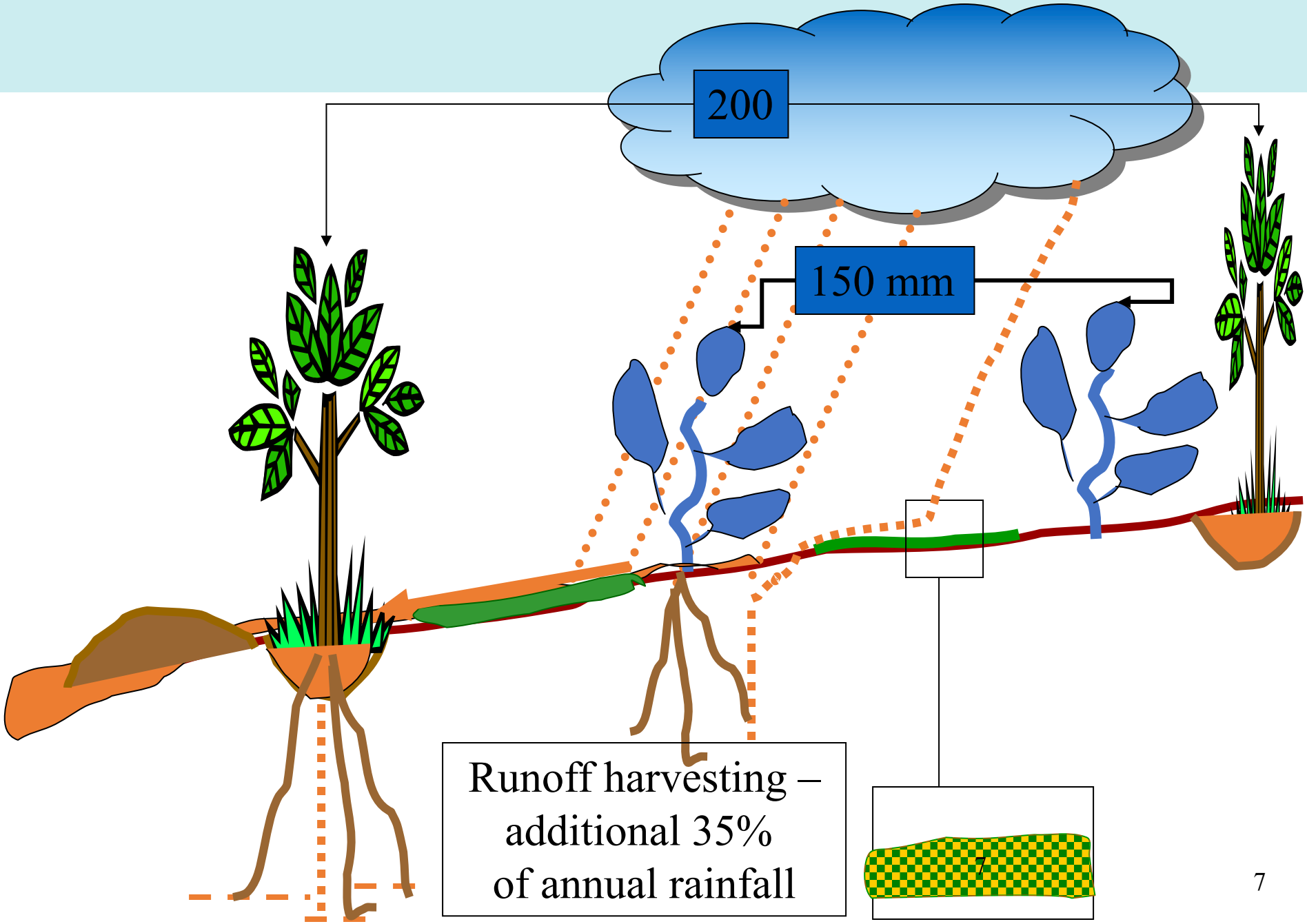



# Definitions

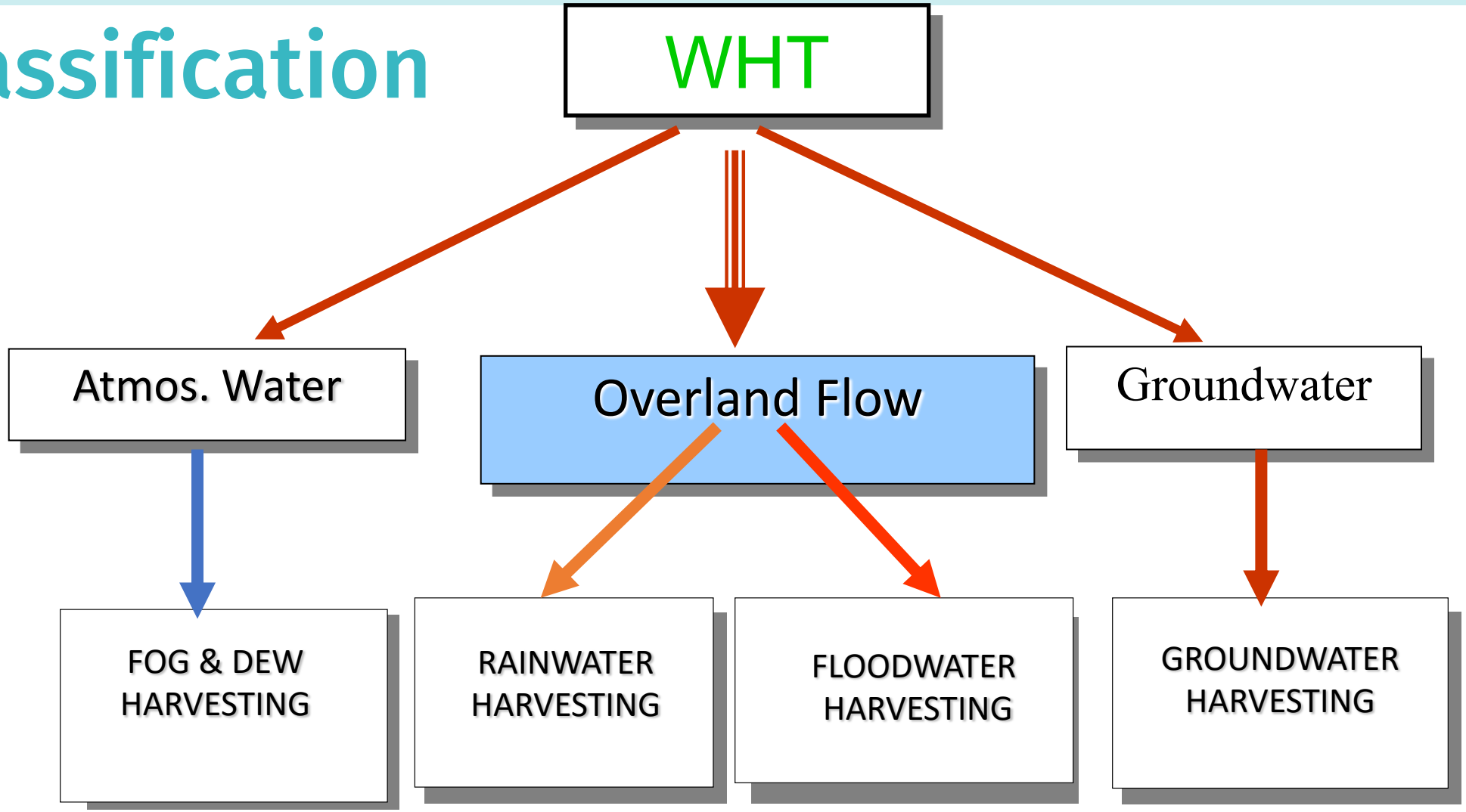
- WH is the practice of collecting water from an area treated to increase runoff from rainfall or snowmelt (Meyers, 1975)

- WH is a method to induce, collect, and conserve local surface runoff for agriculture in arid and semi arid regions (Boers & Ben-Asher, 1982)

- WH is the process of concentrating precipitation, through runoff and storage, for beneficial use (Oweis et al., 2001)

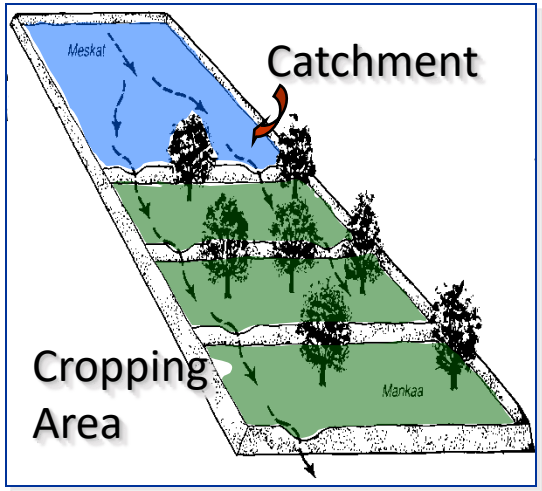

200
150 mm
Runoff harvesting –
additional 35%
of annual rainfall

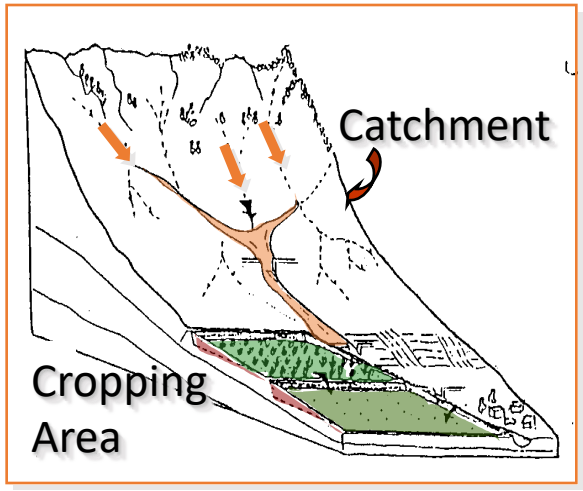
# Classification



# RAINWATER HARVESTING

- Rooftop & Courtyard Water Harvesting
- Micro-catchment Water Harvesting
- Macro-catchment Water Harvesting



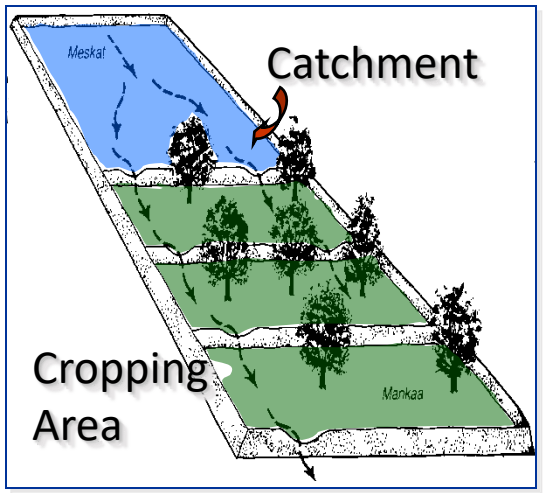
# Development of water harvesting

- As long as the people have inhabited the dry areas and made cultivation, they have harvested water.
- In southern Jordan early WH structures are believed to have been constructed around 5000 years ago,
- Southern Mesopotamia: 4500 BC,
- Negev desert: 1000 BC,
- Yemen (Tihama): spreading system dating 1000 years BC
- Pakistan (Balauchistan): Khuskaba and salaiba systems
- Tunisia: Jessour, meskat and cisterns,
- Egypt (North west and Sina): wadi bed systems and cisterns,
- Moroccco, Syria, Iran, Oman, : Groundwater galleries (fouggara, falej, …).

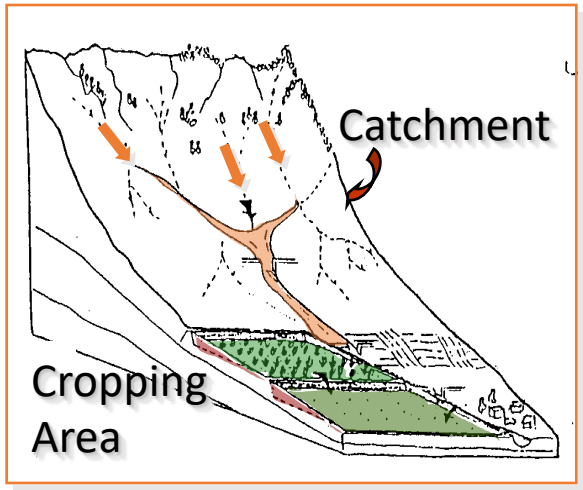
# RAINWATER HARVESTING

**Rooftop & Courtyard Water Harvesting**

**Micro-catchment Water Harvesting**




**Macro-catchment Water Harvesting**



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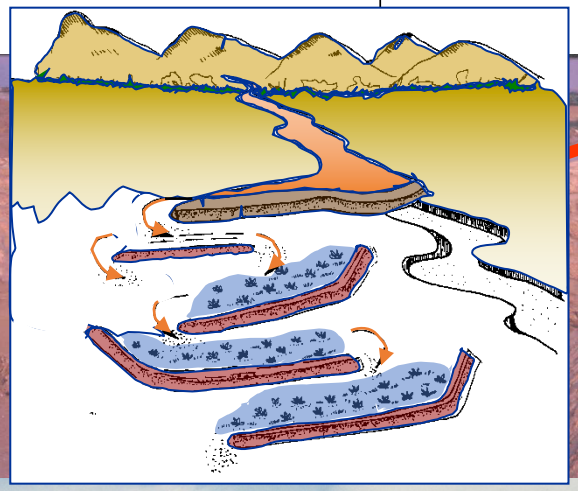
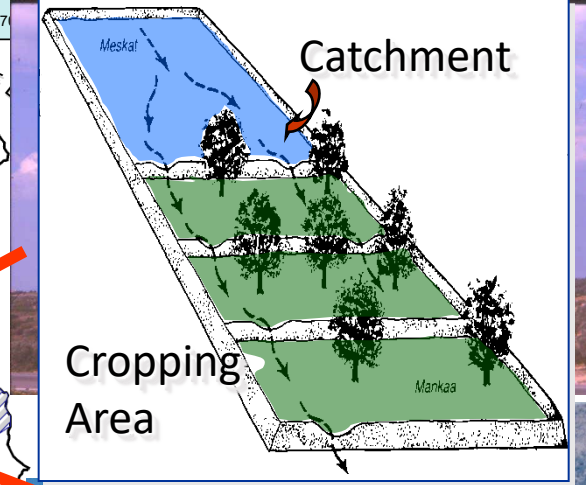
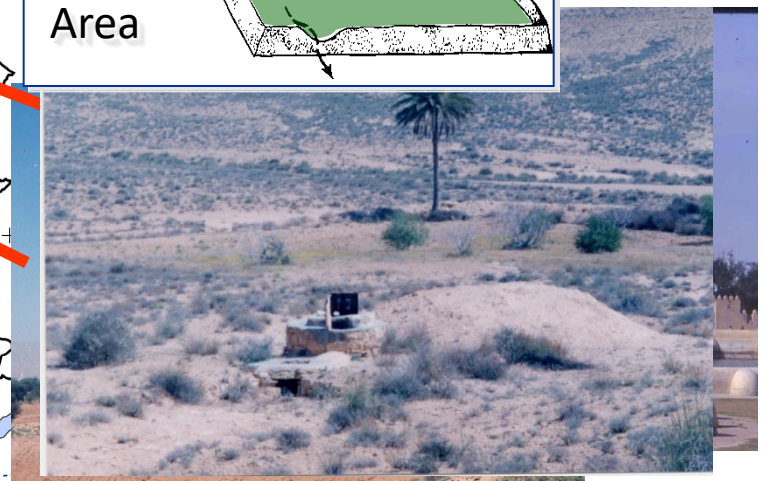
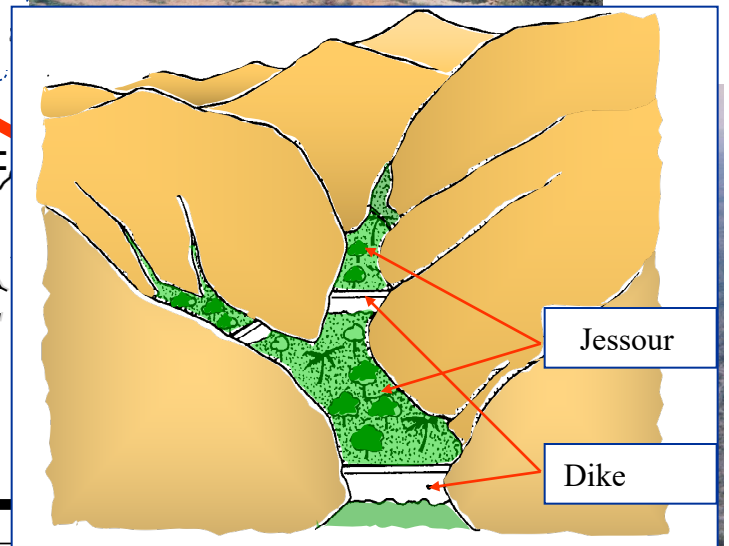



Meskat
Catchment
Cropping
Area
Mankaa

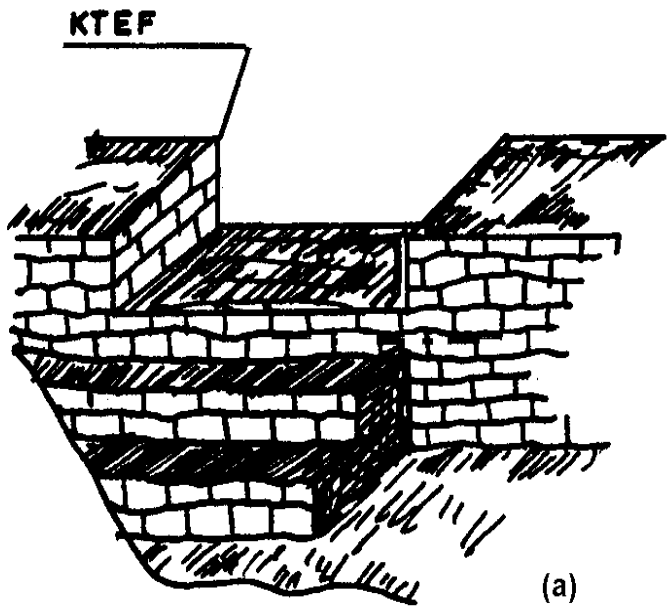


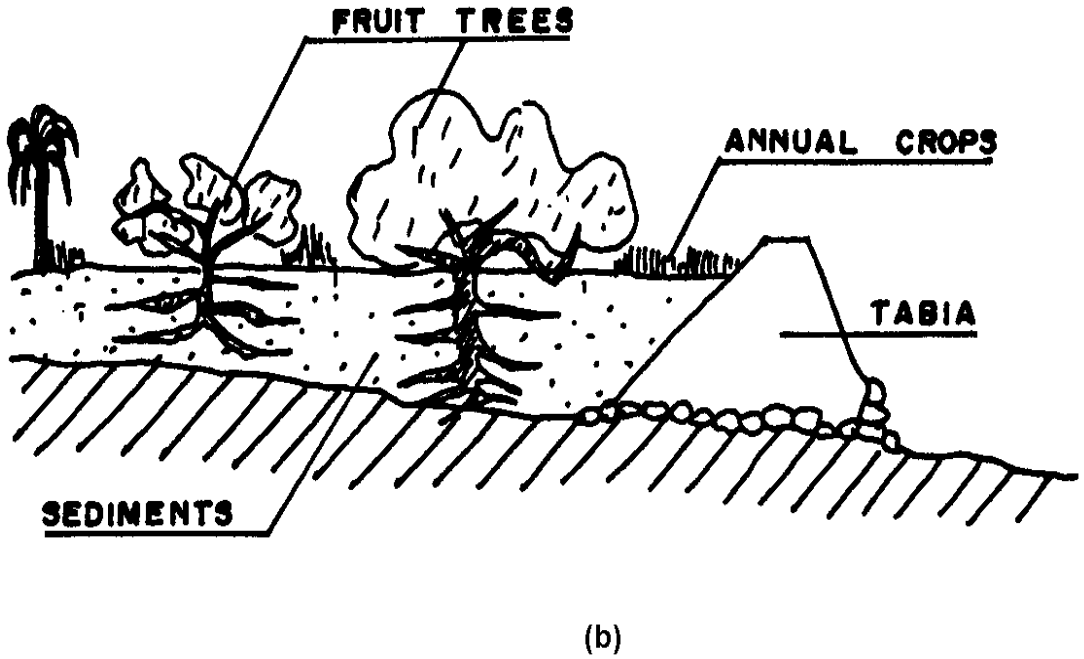

Jessour
Dike

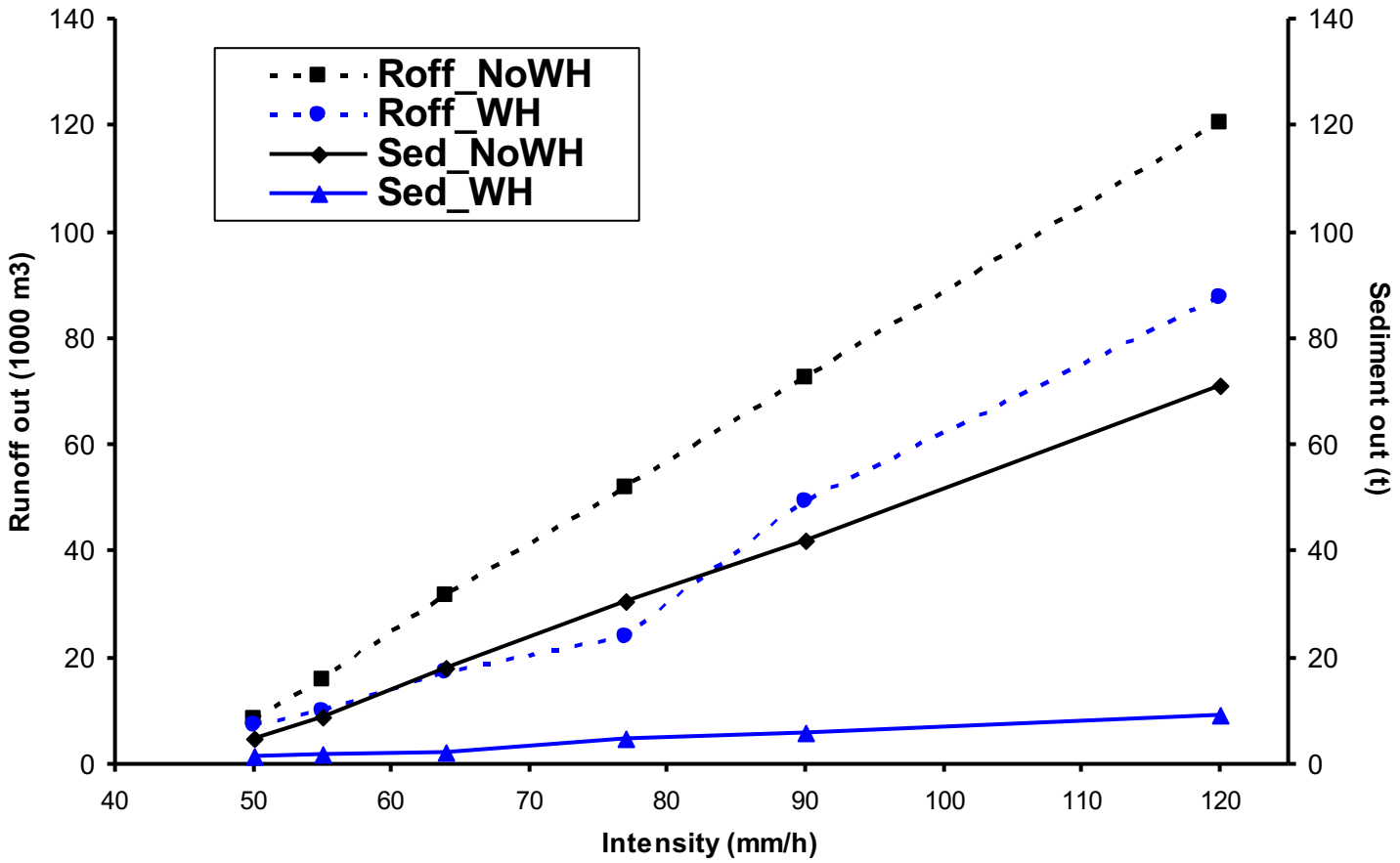
# APPLICATION CASES


# Crop production

# Jessour in Southern Tunisia



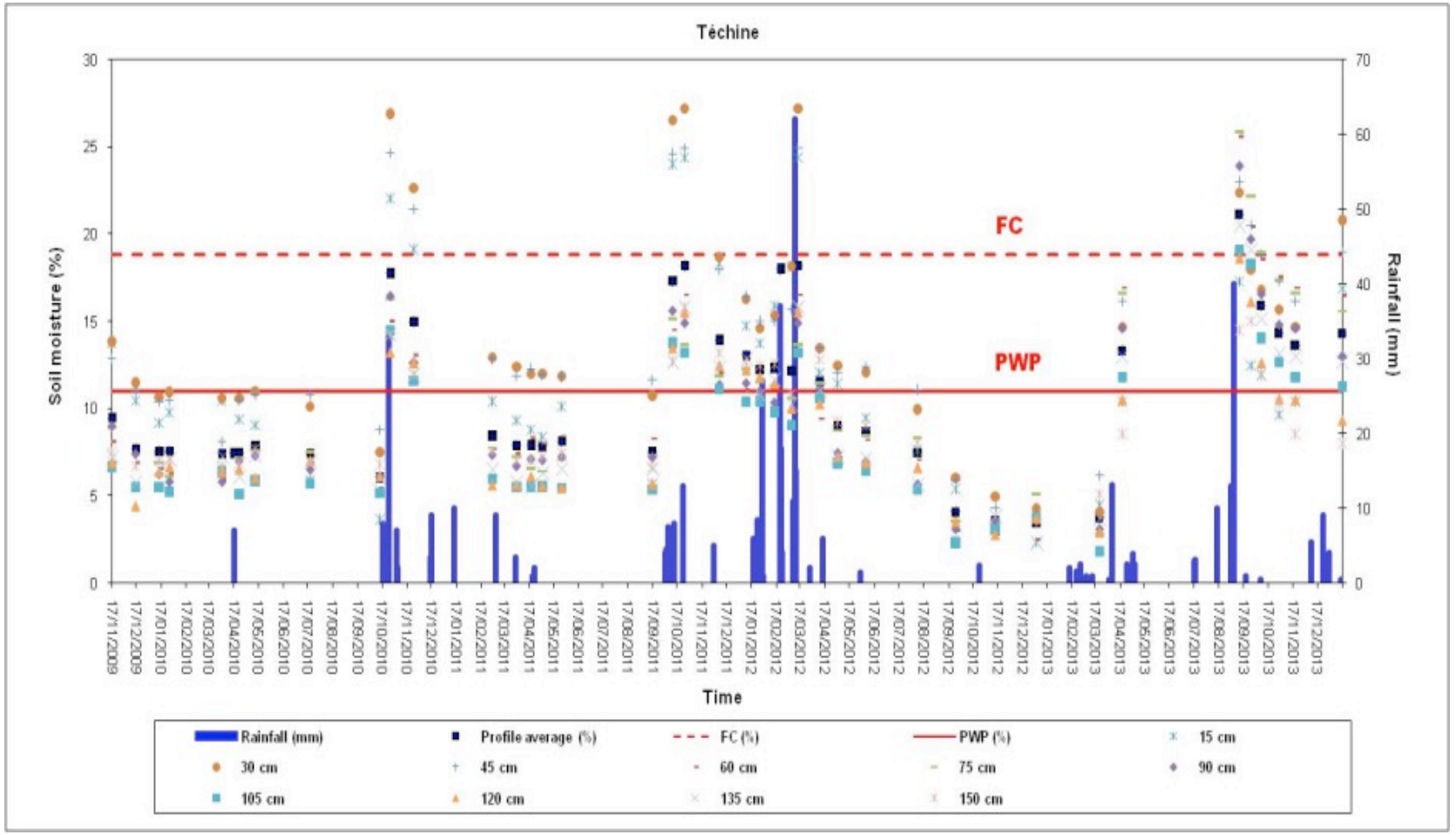



Ouessar, 2007

Schiettecatte et al., 2005; Ouessar, 2007

| Hyd. Year | $ET_{rel}$ (2/1) | $ET_{rel}$ (3/1) | $ET_{rel}$ (3/2) |
|---|---|---|---|
| Wet | 1.1 | - | - |
| Dry | 2.3 | 2.5 | 1.1 |
| Very dry | **12.0** | **15.6** | **1.3** |

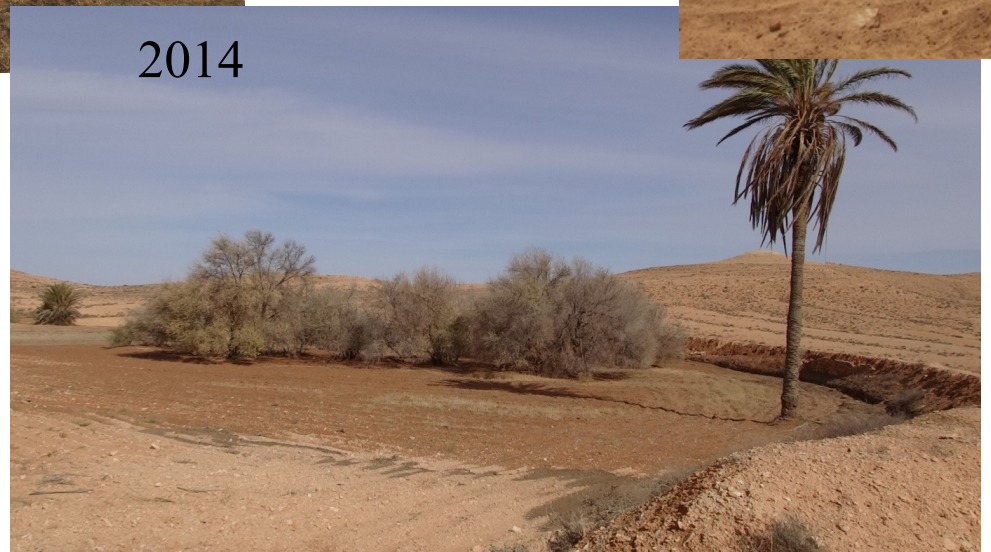
Hyd. Year: type of the hydrological year
ETrel: relative ETa
1: ETa with only rainfall on the terrace
2: ETa with rainfall and runoff on the terrace
3: ETa with rainfall, runoff and supplemental irrigation



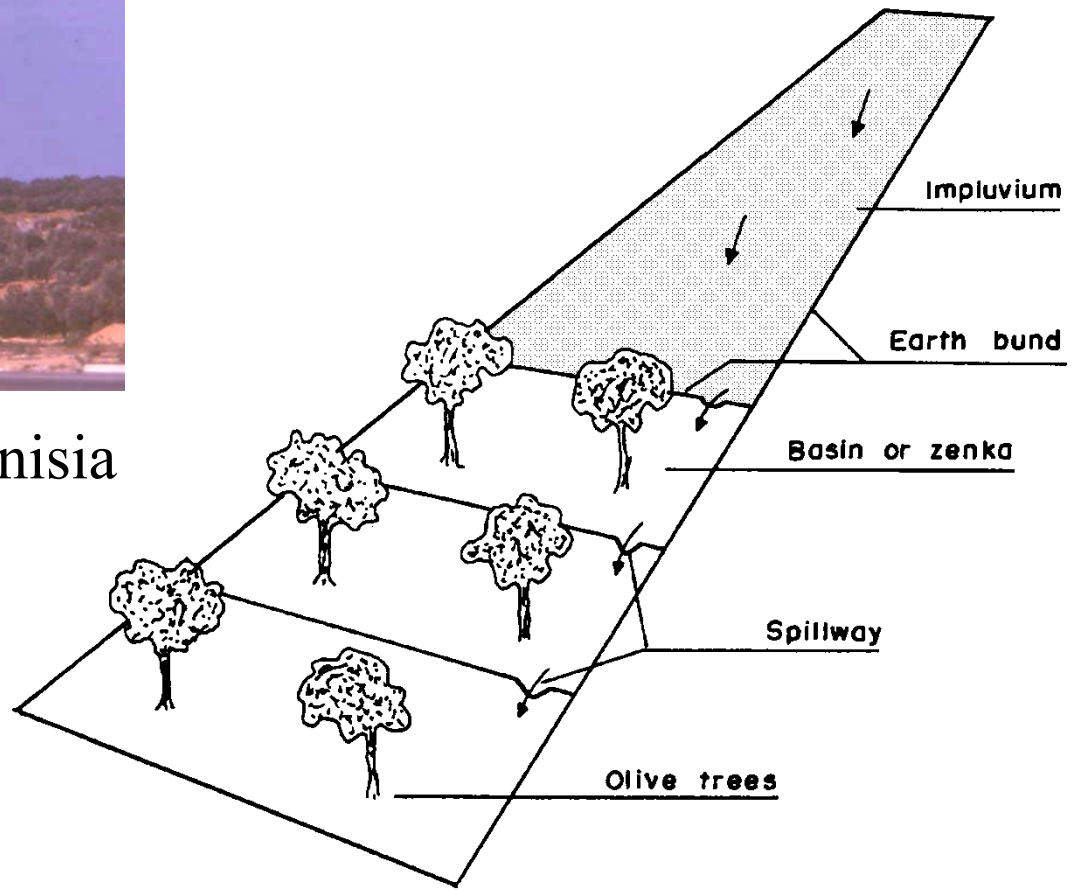

Variation of average soil moisture (% vol.) at different depths in the *jesr* of Techine.

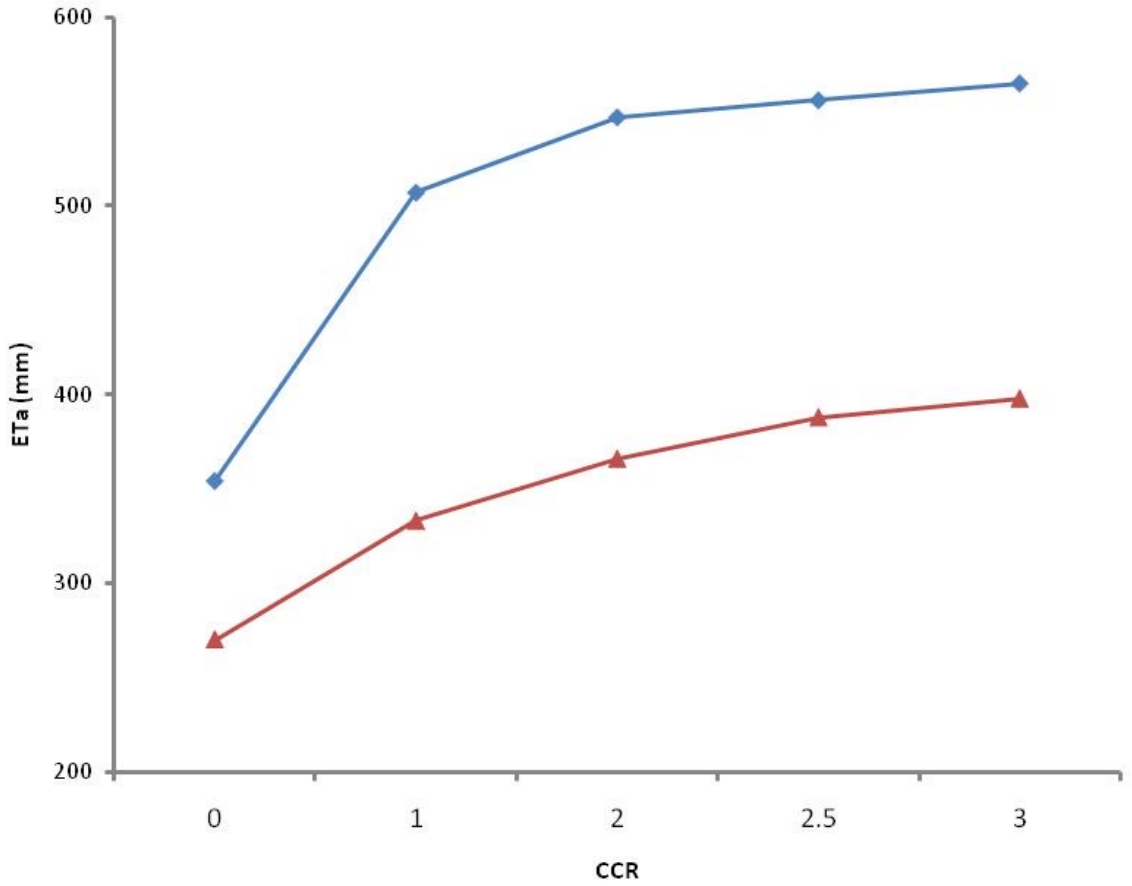
*Abdelli et al., 2017*

# Recurrent droughts and need for SI

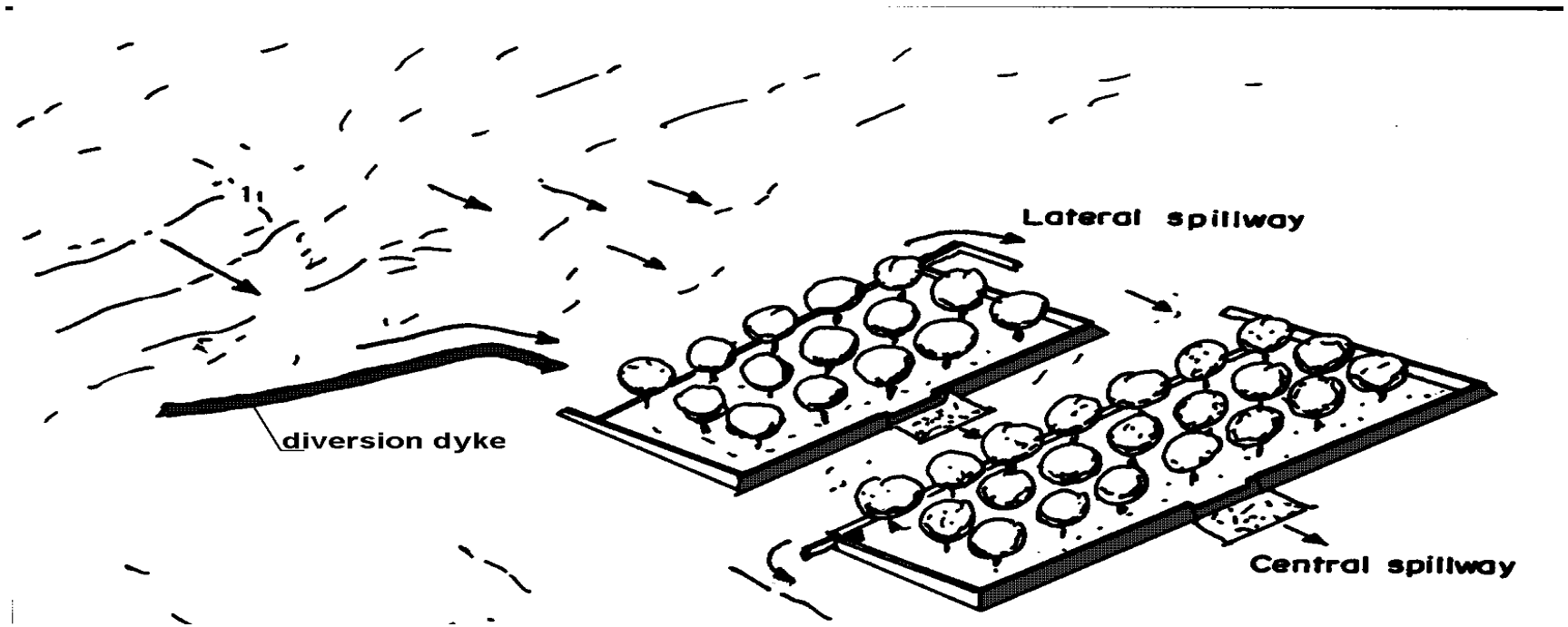
Meskat in the Sahel of Tunisia

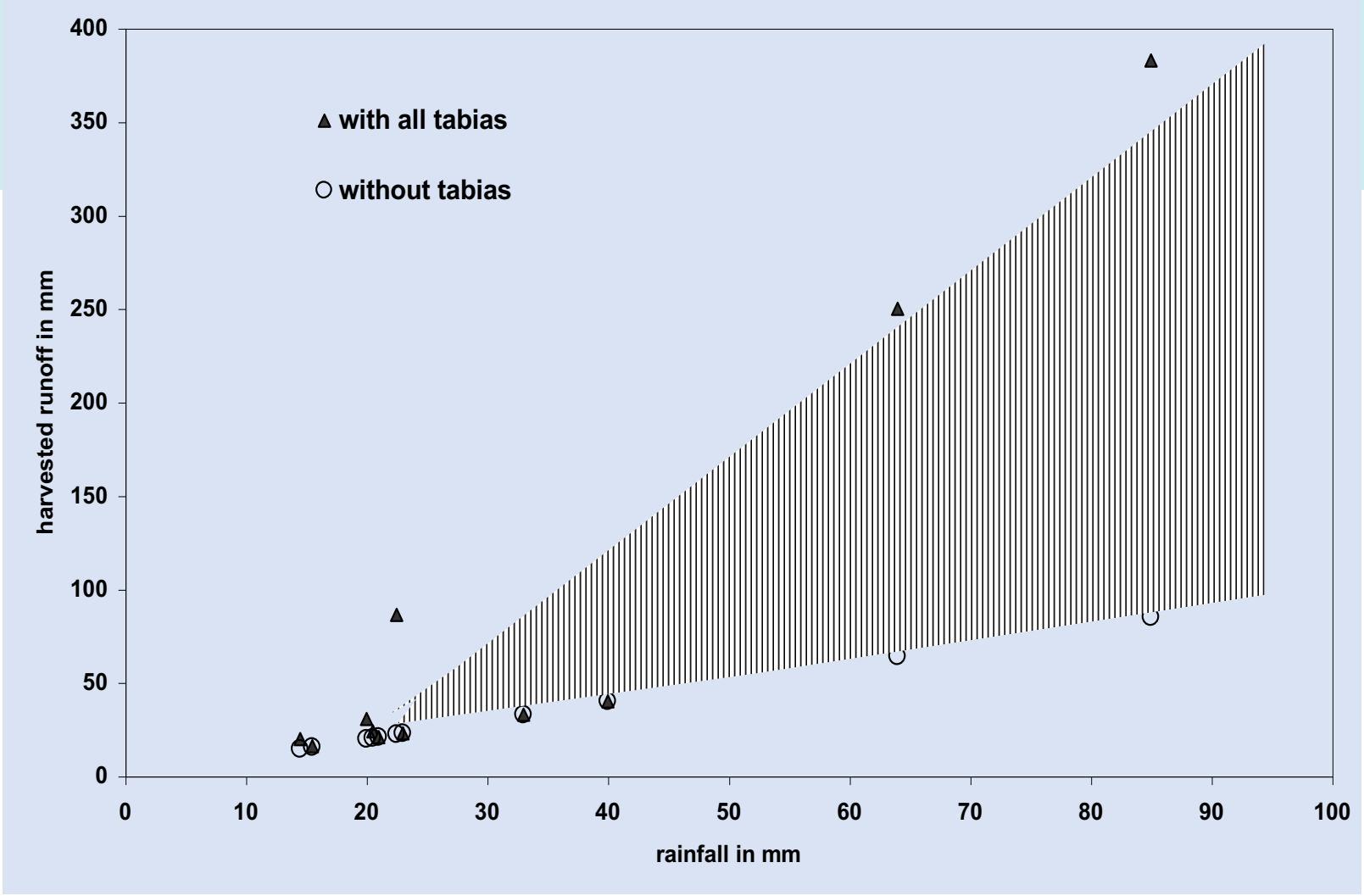





ETa in a Meskat system for different CCR and annual rainfall (green: 413 mm; Red: 290 mm)

# Tabia with natural impluvium in Central Tunisia



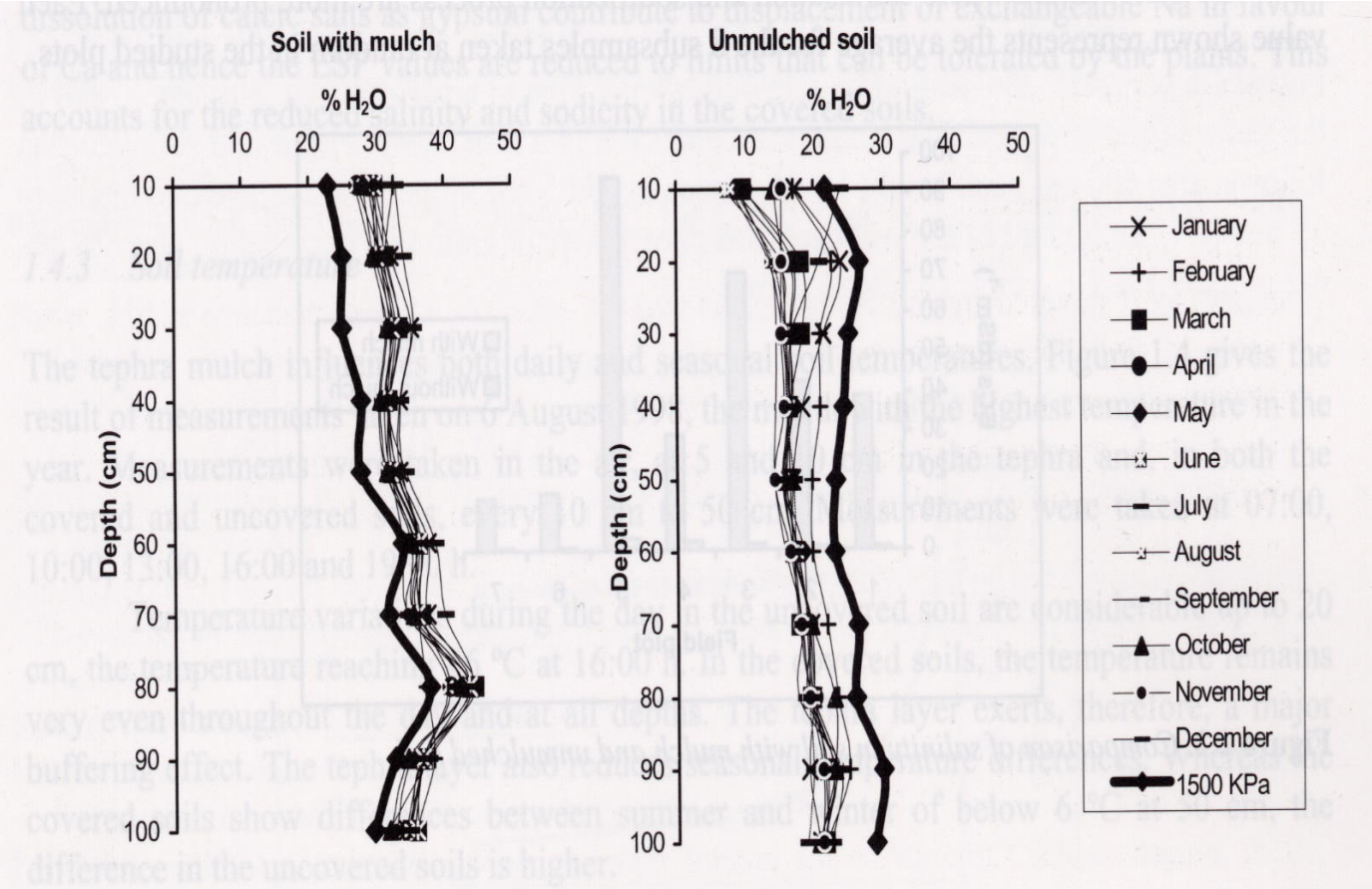



*Nasri et al., 2004*

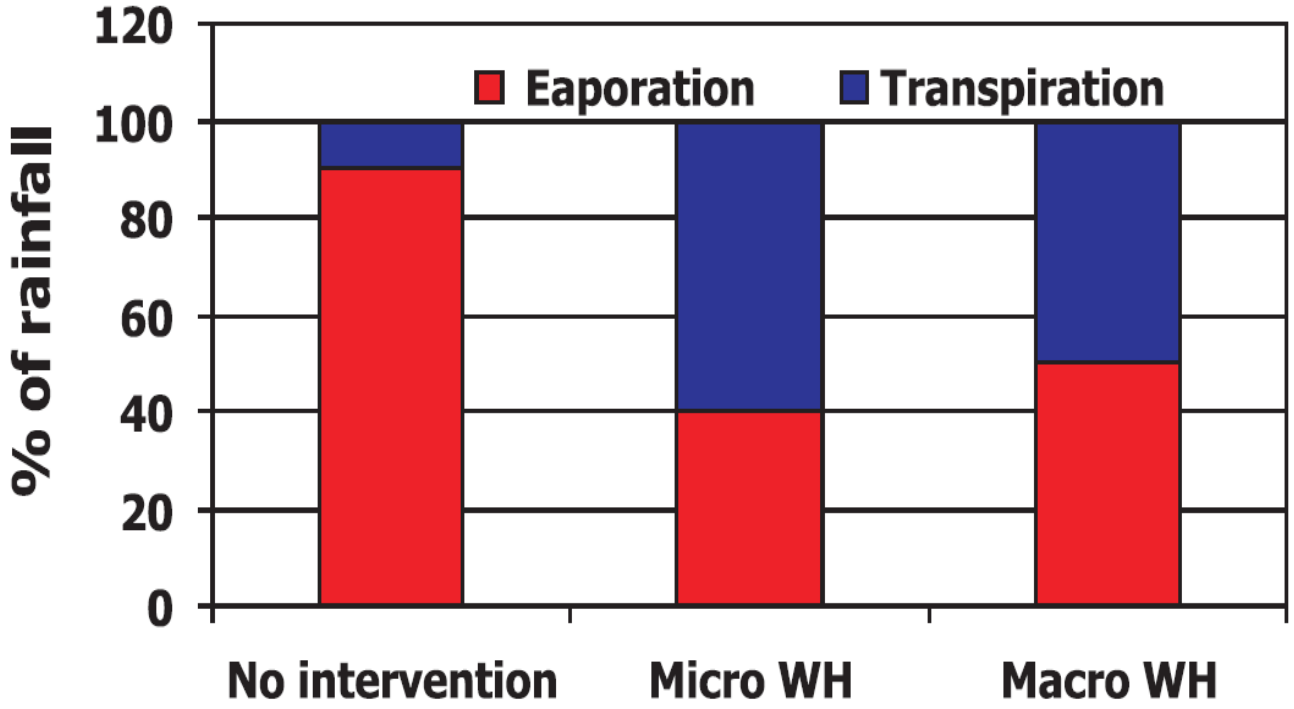
Fruit trees

Annual crops

System of *arenados* at the Islands of Lanzarote (Canaries)




Source: Tejedor et al. (2002)




*Role of water harvesting in shifting nonproductive water evaporation into beneficial transpiration.*

*(Oweis et al., 1999; Oweis, 2006)*

# Fodder production


**Table 3.15. Vegeation cover and plant height increase for *Atriplex* and *Salsola* species in the Vallerani experiment at different spacing treatments (catchment areas) during the 2005/06 growing season (until June).**

| Catchment area | *Atriplex* spp. | | *Salsola* spp. | |
|---|---|---|---|---|
| | Cover (%) | Height (cm) | Cover (%) | Height (cm) |
| Control | 17 b | 13 b | 17 c | 7 b |
| 5 m (14 $m^2$) | 85 a | 25 b | 78 a | 33 a |
| 10 m (28 $m^2$) | 82 a | 42 a | 62 b | 35 a |

Karrou et al., 2011

**Table 6.** Forages and fodder productivity improvement in watershed treated with rainwater and soil conservation measure in India

| Watershed | State | Productivity (t/ha) | | |
|---|---|---|---|---|
| | | Pre-treatment | Post treatment | % increase |
| Sukhomajri | Haryana | 2.47 | 5.05 | 104 |
| Bunga | Haryana | 0.20 | 3.20 | 1500 |
| Bazar Gunyar | Haryana | 0.10 | 0.50 | 400 |
| Chhajawa | Rajasthan | 0.10 | 5.42 | 4420 |
| Navamota | Gujarat | 1.00 | 2.00 | 100 |
| Chhinatekur | A.P. | 0.88 | 11.60 | 1218 |
| G.R.Halli | Karnataka | 1.50 | 8.19 | 446 |
| Fakot | Uttarakhand | 3.90 | 12.0 | 208 |
| Average | | 1.27 | 5.95 | 372 |

Samra, 2015

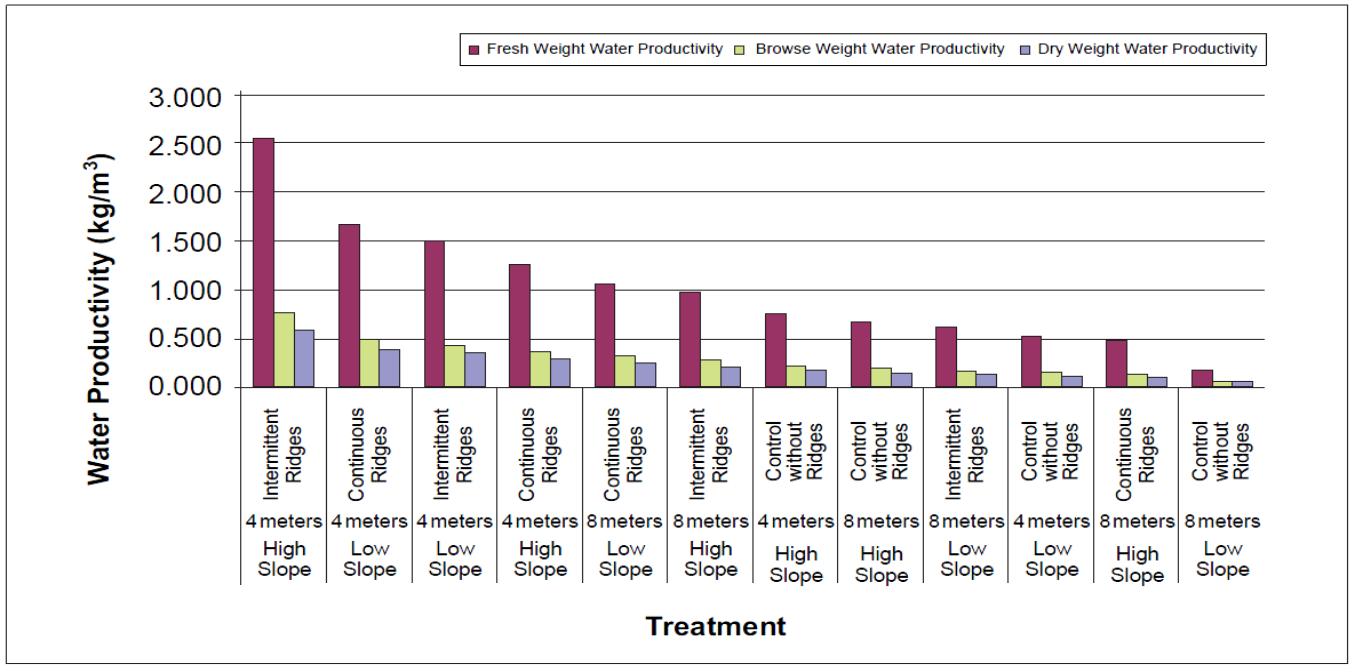
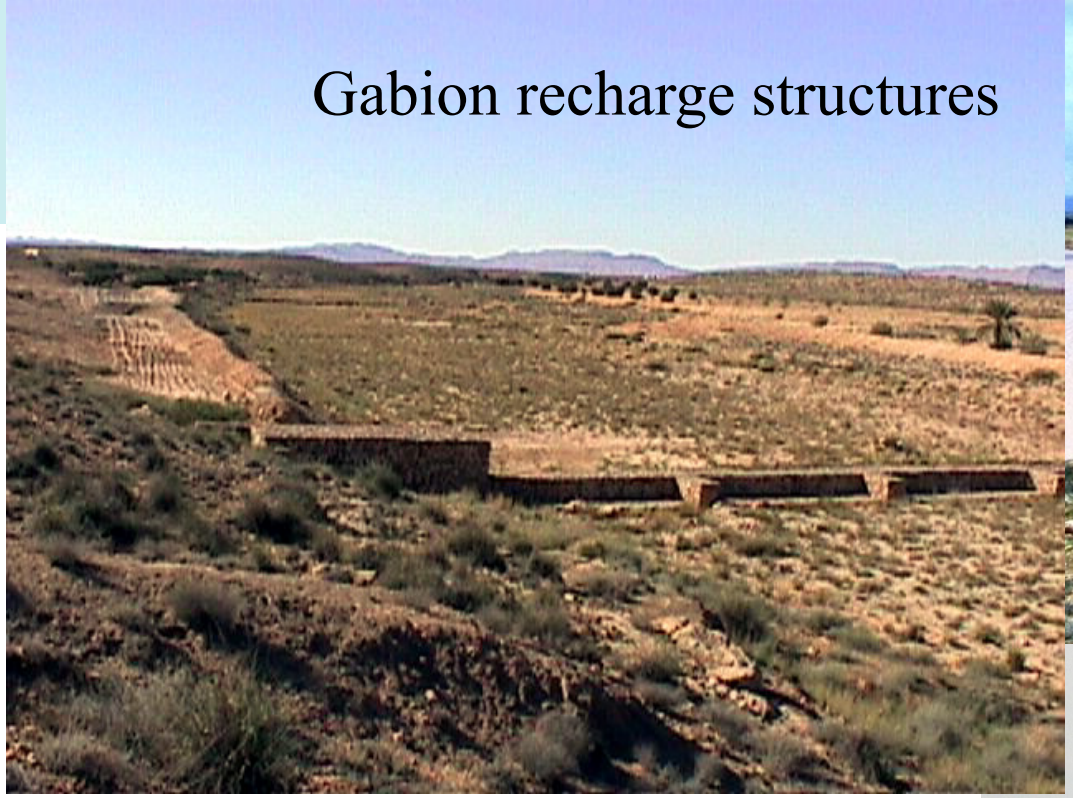



**Figure 2.17. Water productivity of Atriplex shrubs as affected by WHT, spacing between contour ridges, and land slope (2006/07 season).**

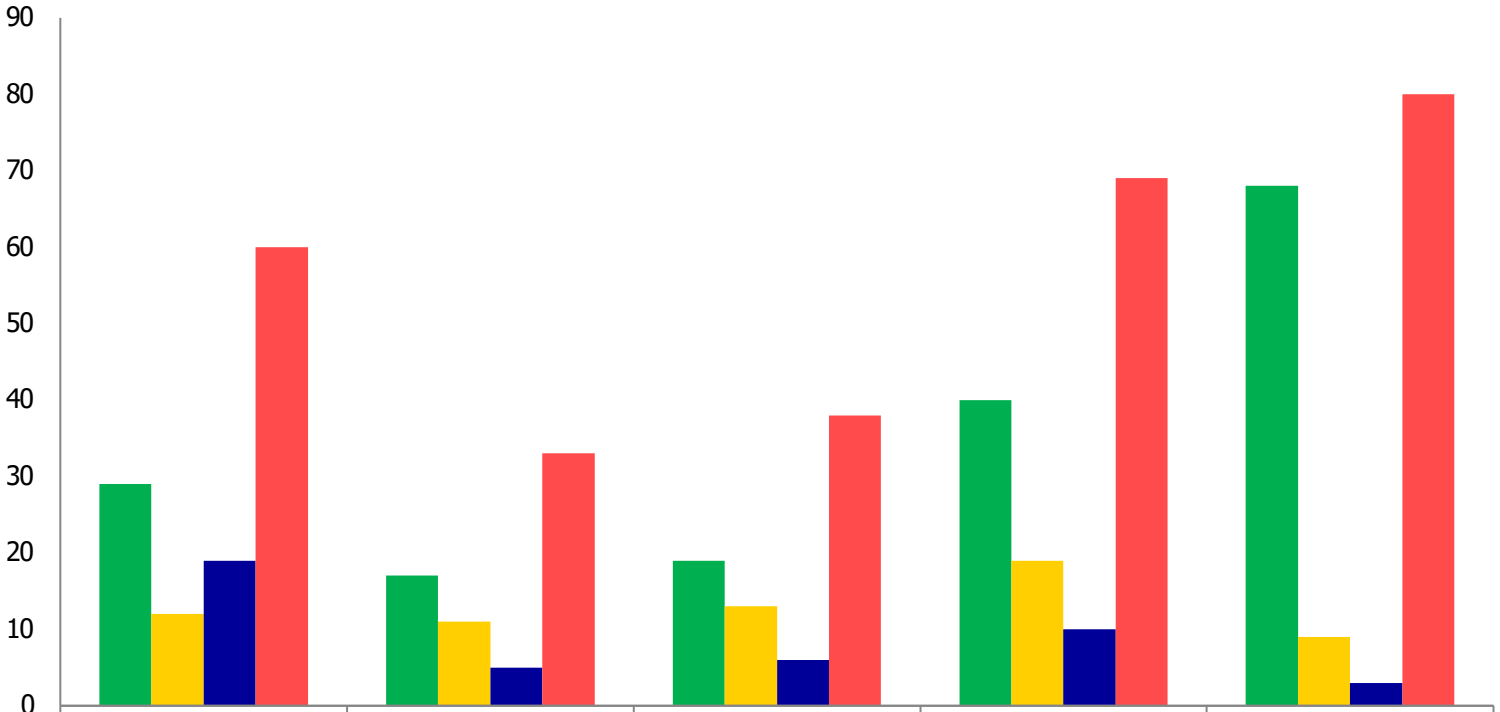
Mudabbar et al, 2011

# Groundwater recharge

# Gabion recharge structures



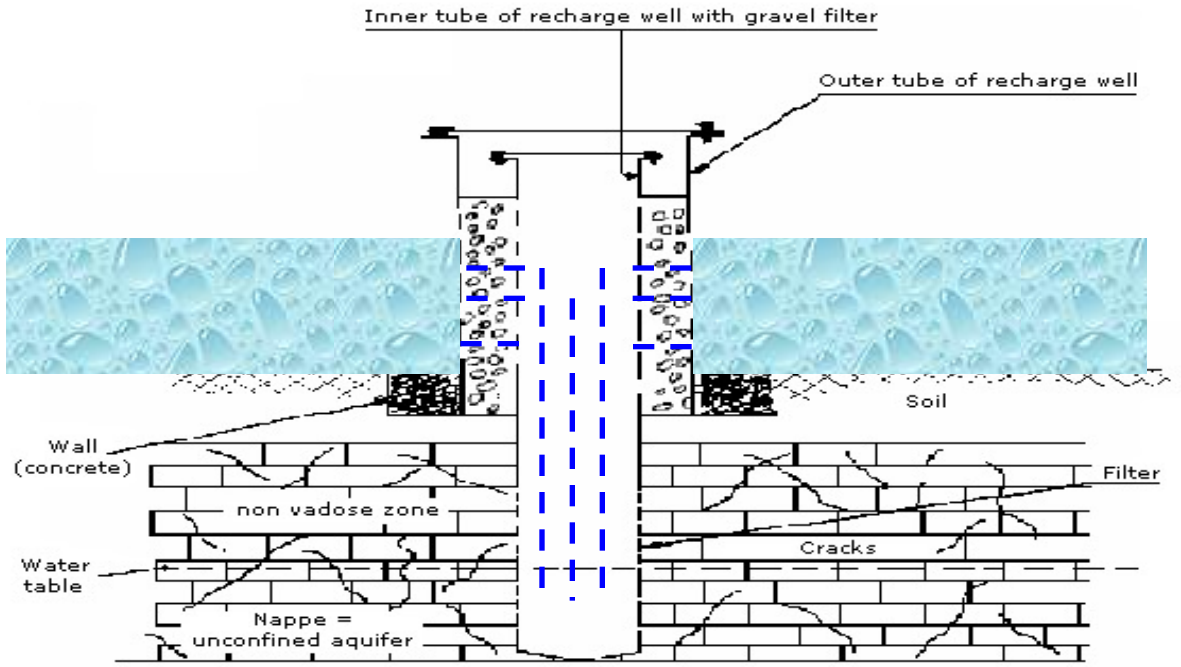
# Loss in storage capacity




| | 0% - 10% | 11% - 30% | 31% - 50% | 51% - 80% | 81% - 100% |
|---|---|---|---|---|---|
| Amont | 29 | 17 | 19 | 40 | 68 |
| Centre | 12 | 11 | 13 | 19 | 9 |
| Aval | 19 | 5 | 6 | 10 | 3 |
| Total | 60 | 33 | 38 | 69 | 80 |

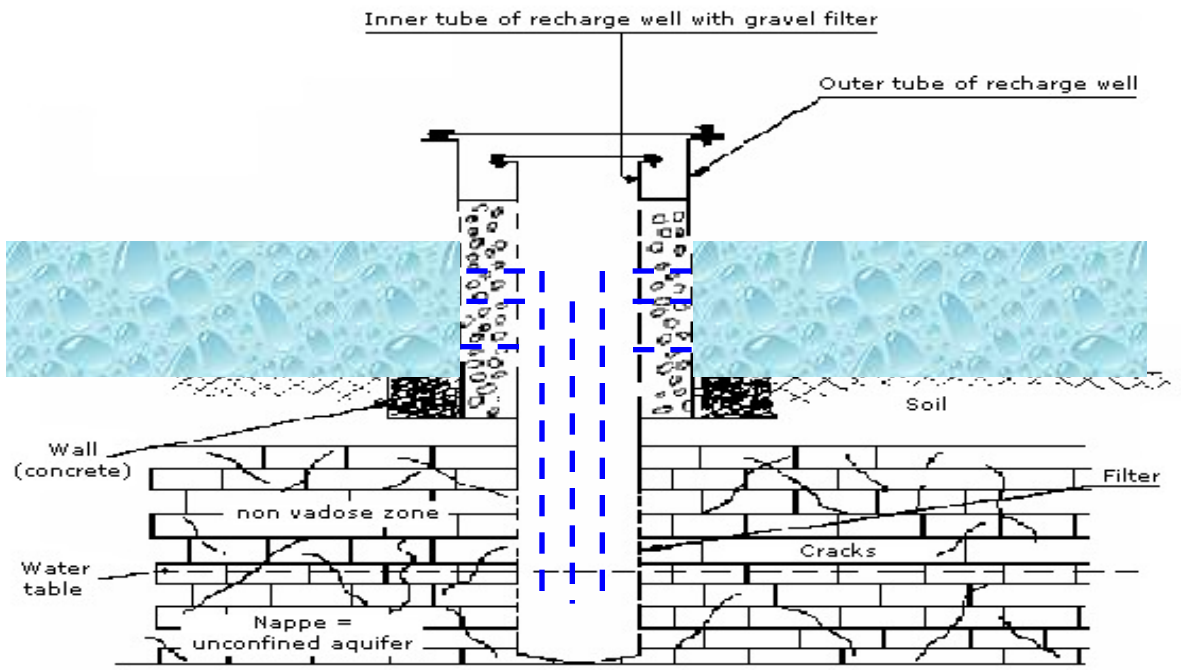
Nawab & Ouessar, 2013

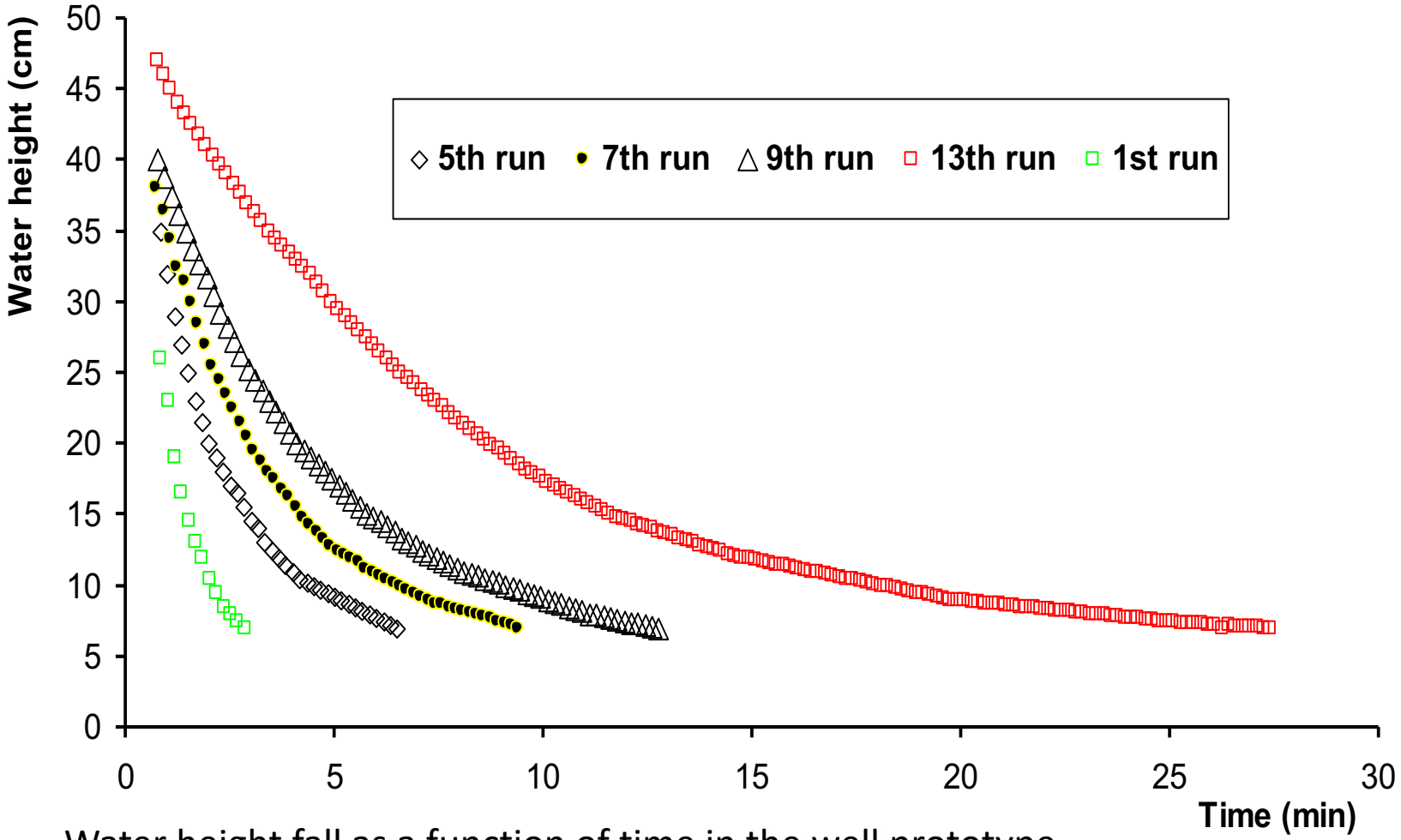
# Groundwater recharge wells



Saudi Arabia

# Recharge wells

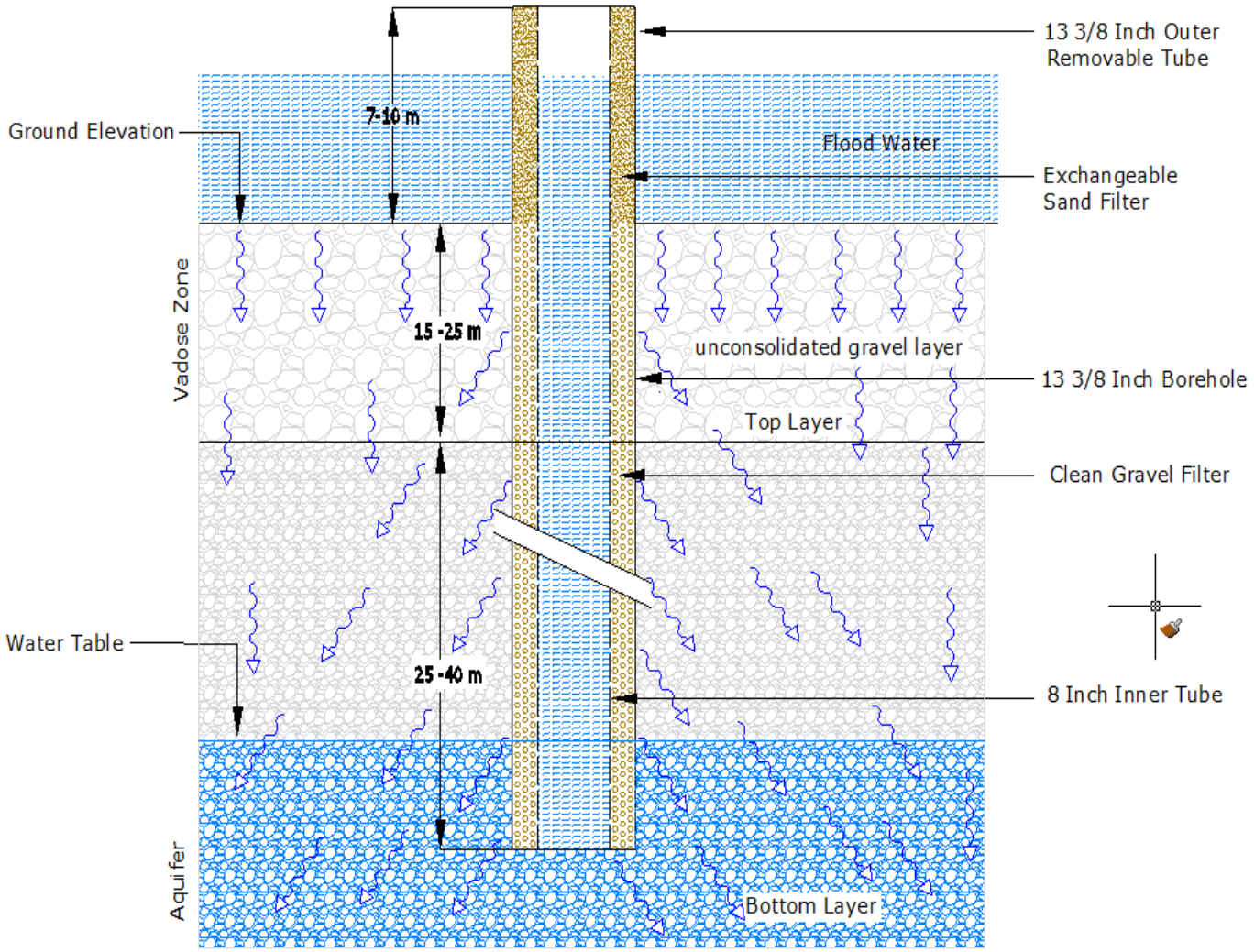


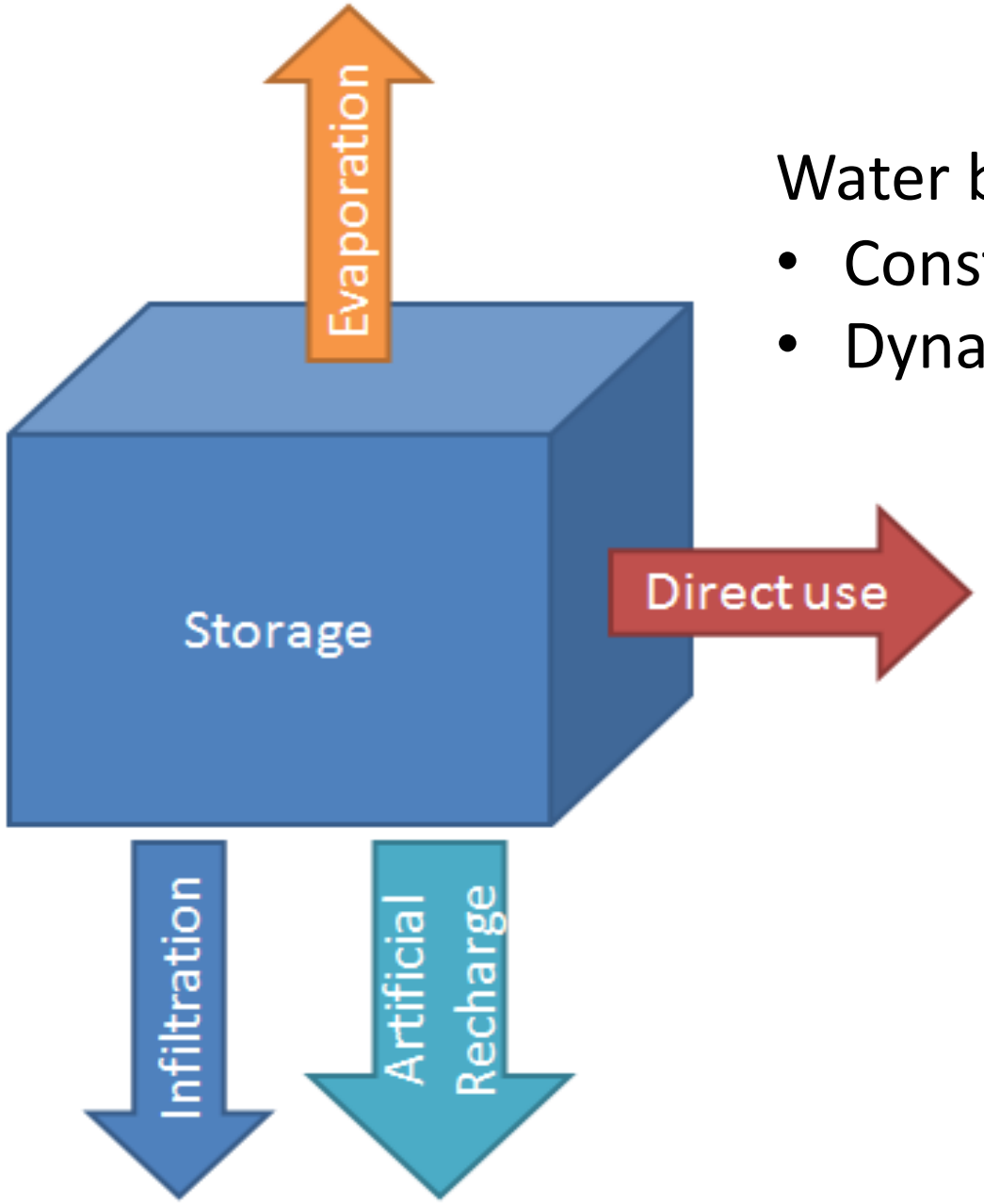



Water height fall as a function of time in the well prototype

Ouessar, 2007

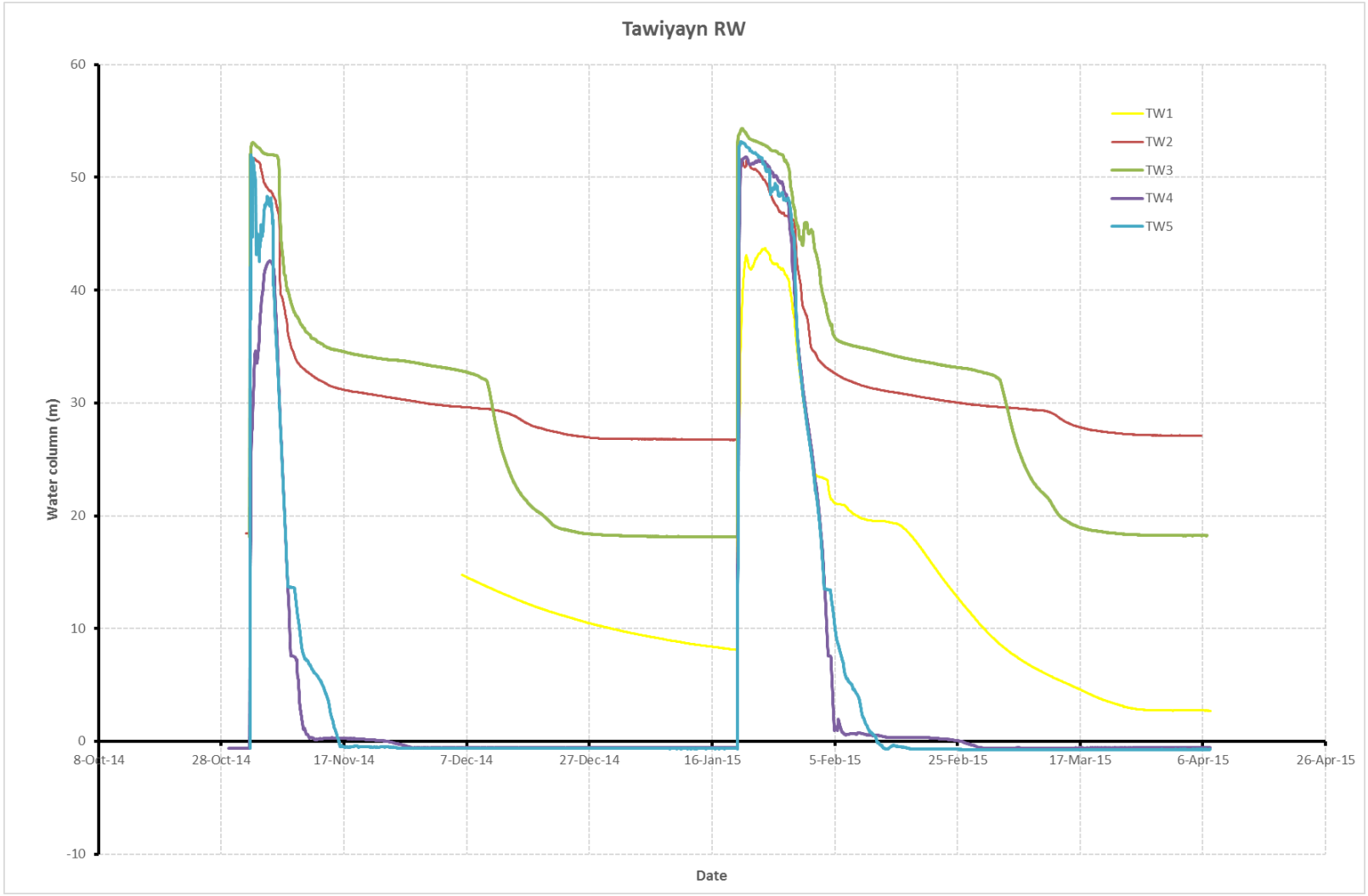
Experience from UAE


13 3/8 Inch Outer
Removable Tube
Ground Elevation
7-10 m
Flood Water
Exchangeable
Sand Filter
Vadose Zone
15 -25 m
unconsolidated gravel layer
13 3/8 Inch Borehole
Top Layer
Clean Gravel Filter
Water Table
25 -40 m
8 Inch Inner Tube
Aquifer
Bottom Layer

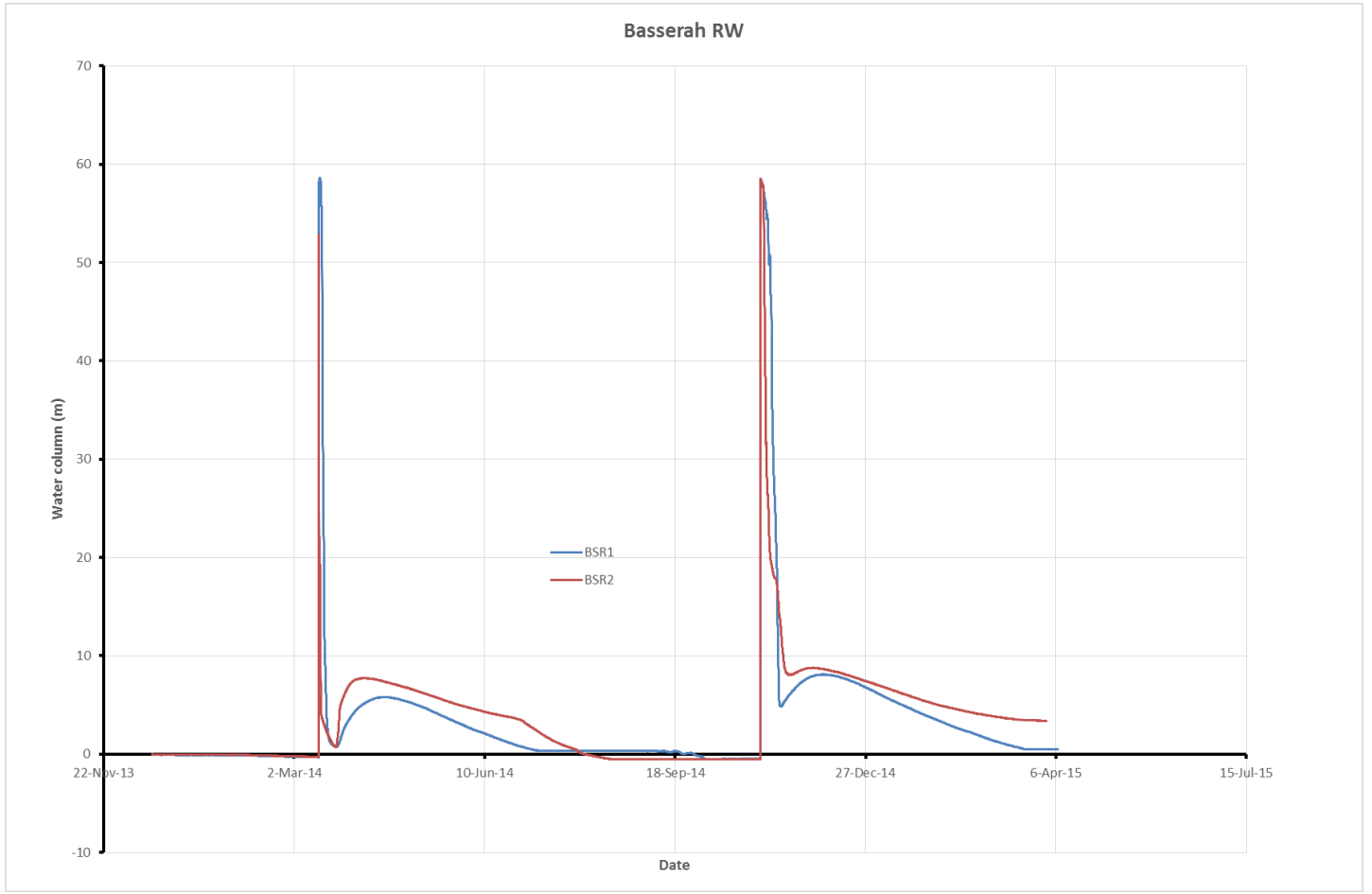



Water balance approach

- Constant head
- Dynamic head

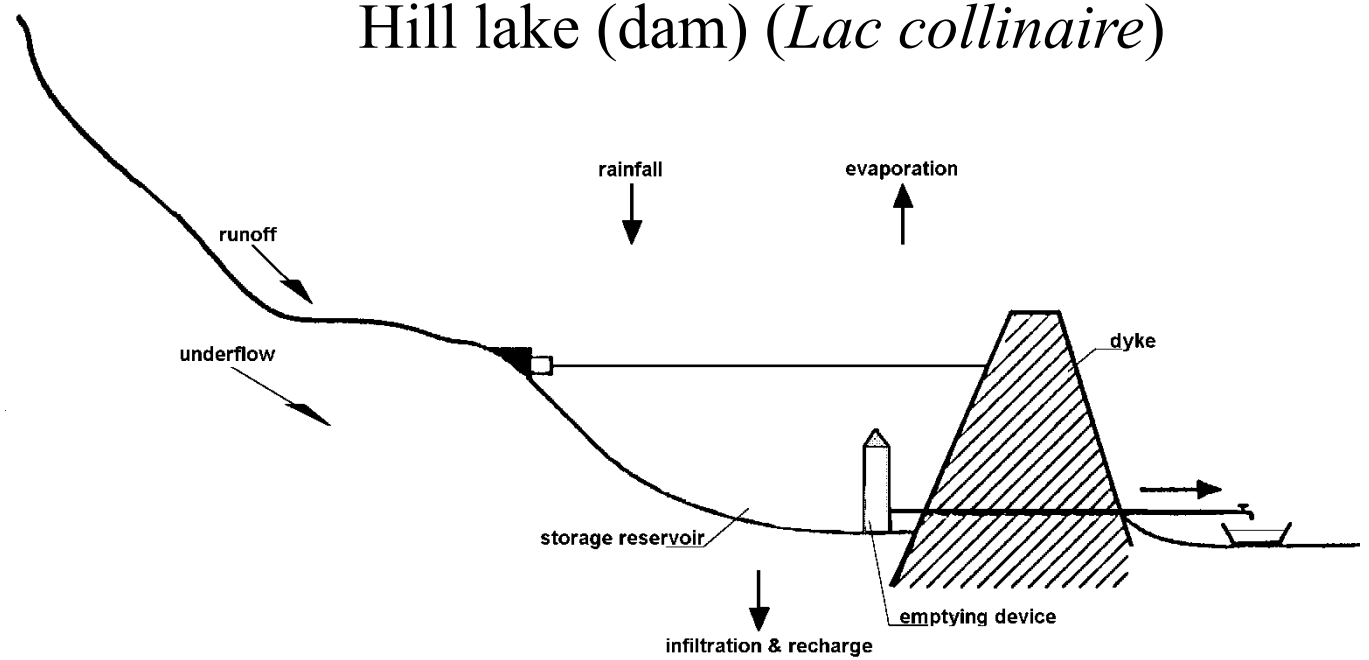


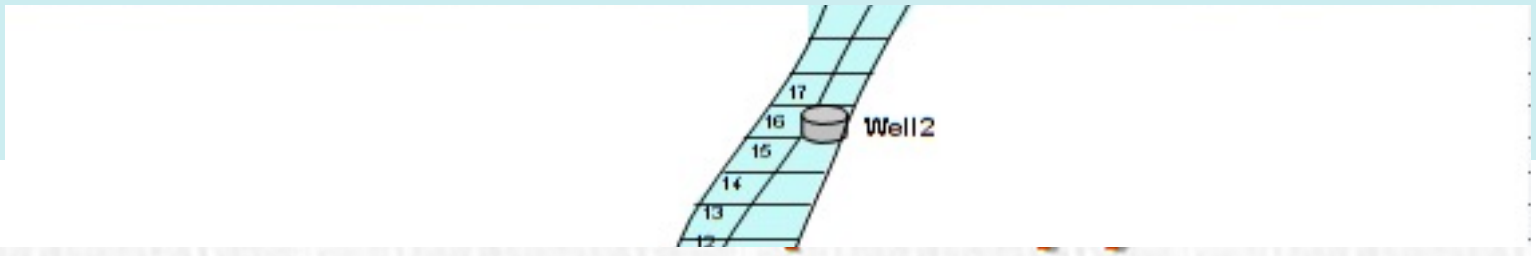

*INWEH & MoEW, 2016*

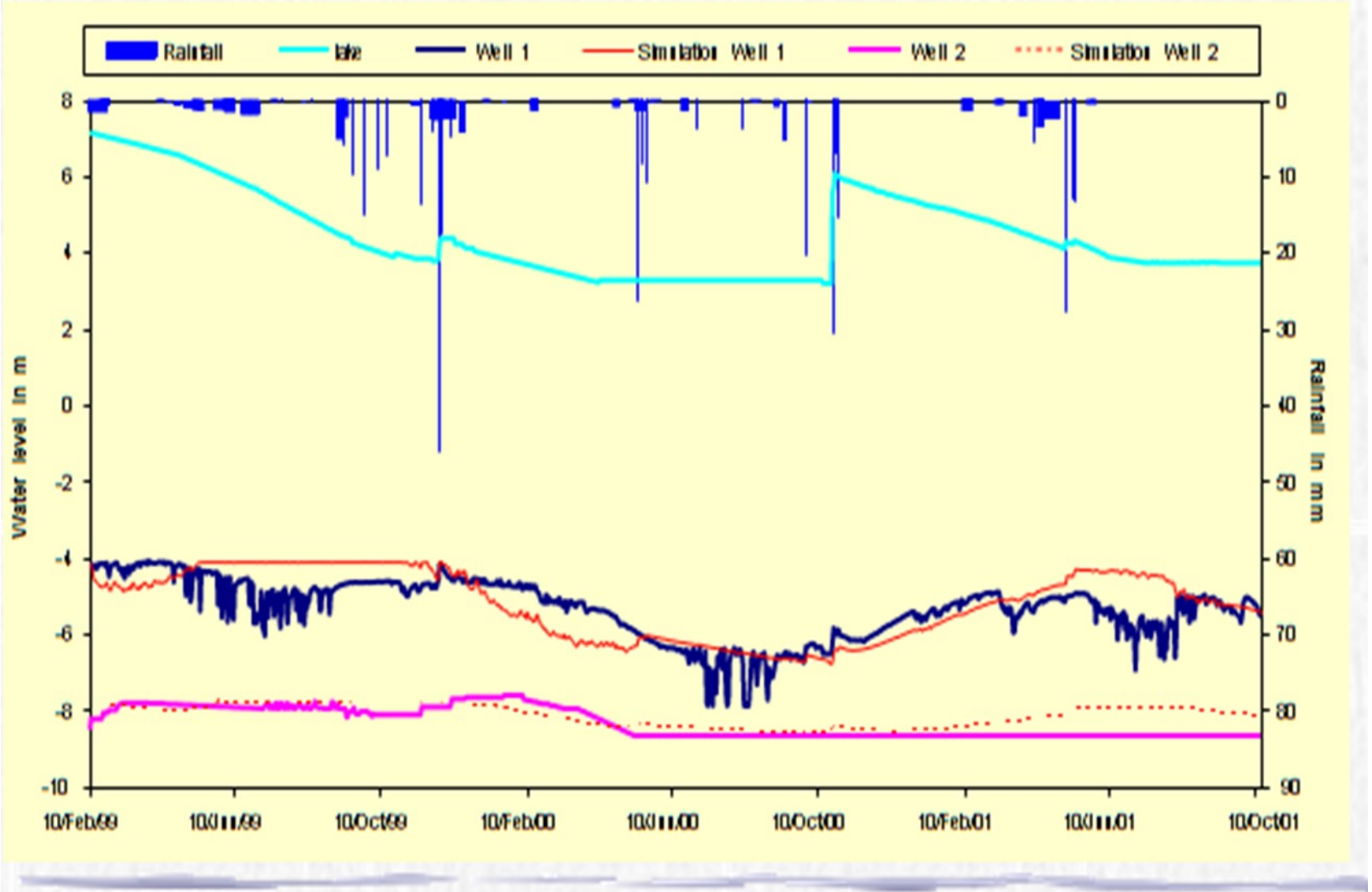


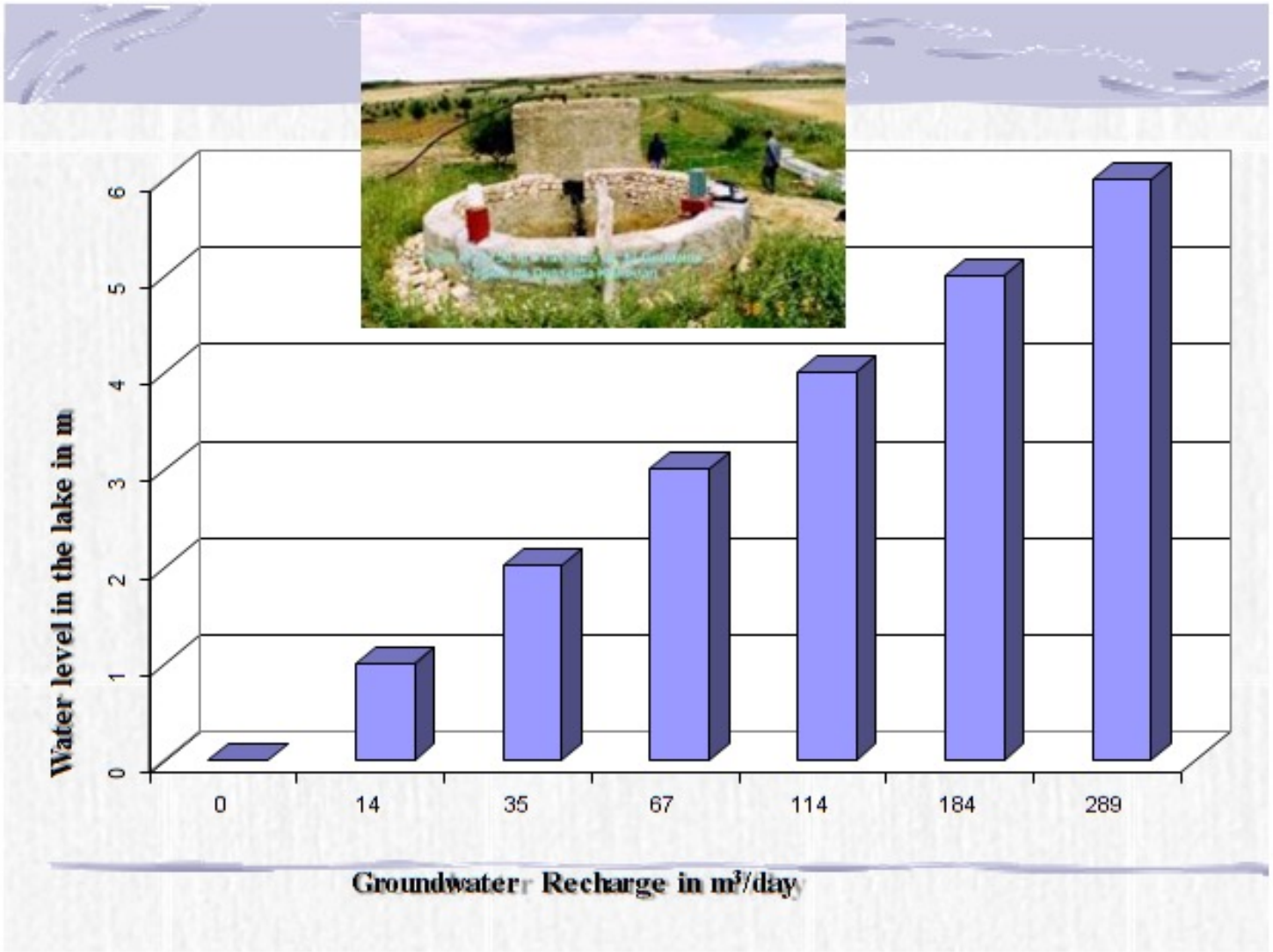

*INWEH & MoEW, 2016*

# Hill lake (dam) (*Lac collinaire*)



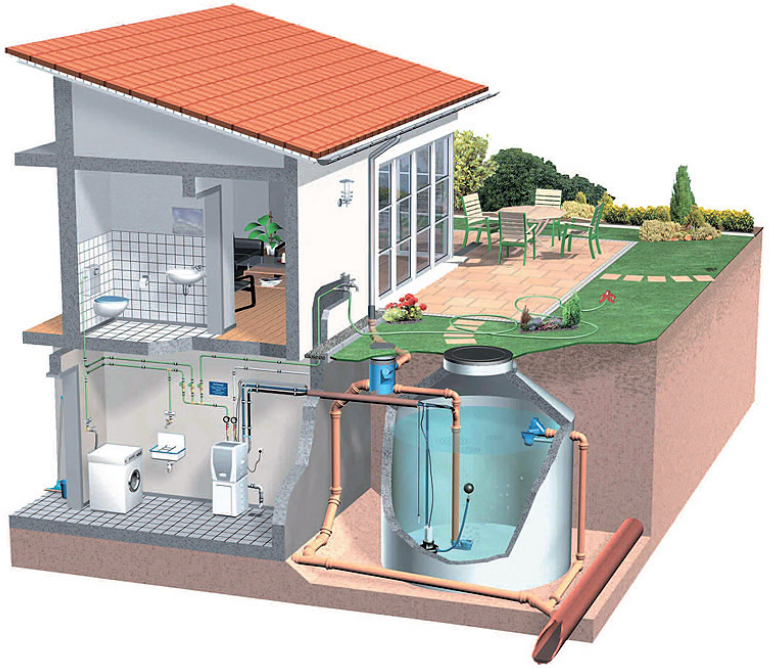

17
16
15
14
13
Well2


Rainfall
lake
Well 1
Simulation Well 1
Well 2
Simulation Well 2
Water level in m
Rainfall in mm
8
6
4
2
0
-2
-4
-6
-8
-10
0
10
20
30
40
50
60
70
80
90
10/Feb/99
10/Jun/99
10/Oct/99
10/Feb/00
10/Jun/00
10/Oct/00
10/Feb/01
10/Jun/01
10/Oct/01

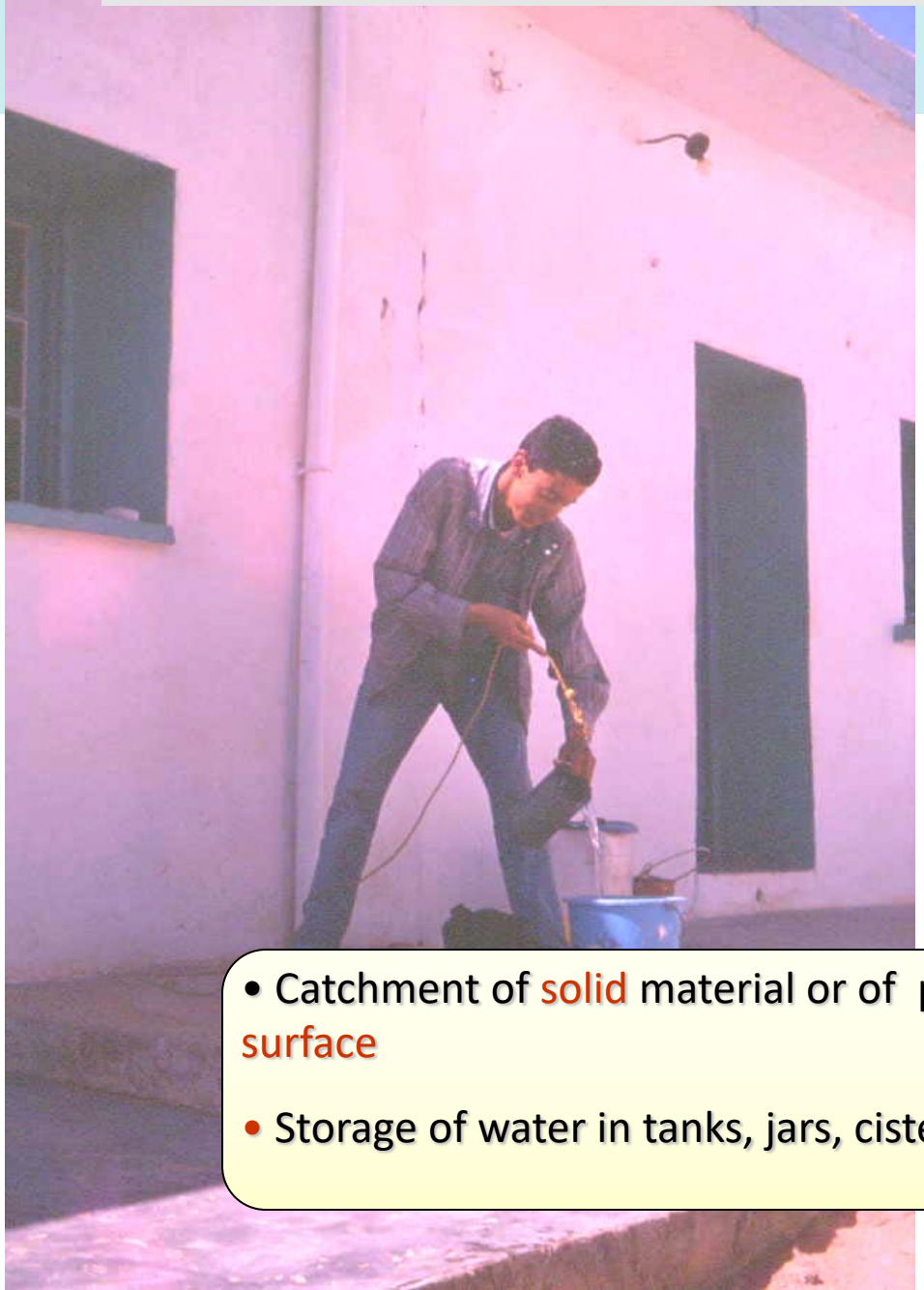

Water level in the lake in m
0
1
2
3
4
5
6
0
14
35
67
114
184
289
Groundwater Recharge in m³/day

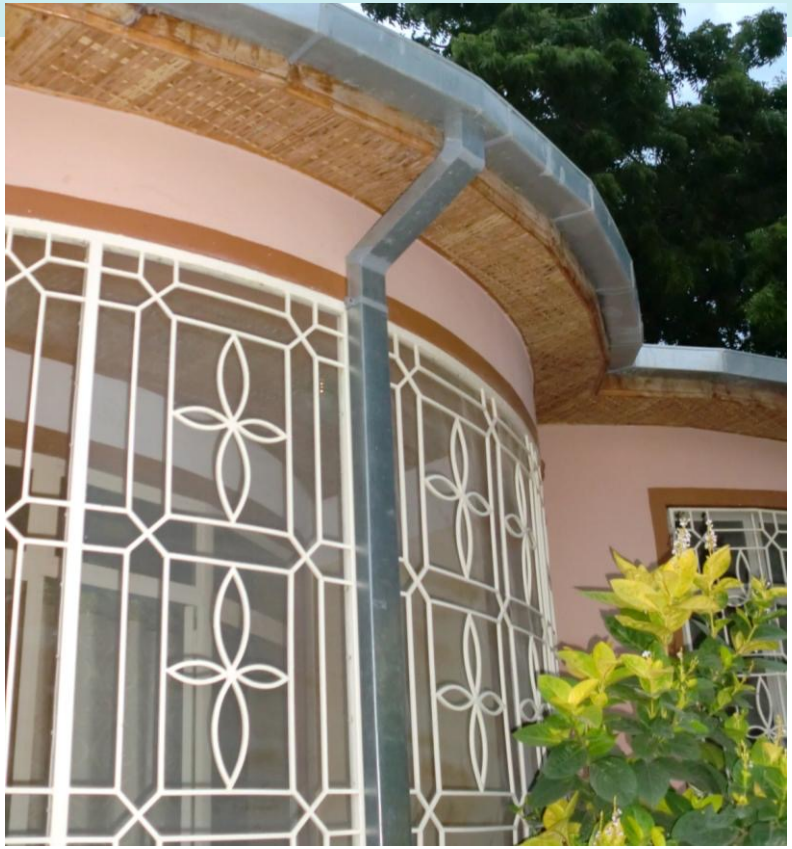
# Watering / Drinking


POLYTANK



# Rooftop and Courtyard Water Harvesting





- Catchment of solid material or of paved, bituminized, compacted (= treated) surface
- Storage of water in tanks, jars, cisterns

# FOG AND DEW HARVESTING (Prinz, 1994)

Fog drip is provoked by:

- Substantial heating during day time
- Clear skies or very light, high clouds at night
- No or very light wind
- A thermal inversion at moderate height
- A sufficiently high atmospheric humidity

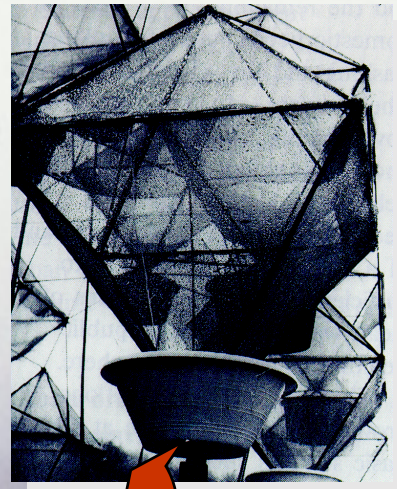
Examples:

In South America: The desert along the coast of Chile and Peru

In Central and North America: Along the coast of the Californian peninsula in Mexico up to 34 $^{0}$ N, near Los Angeles

In Africa: Along the Atlantic coast of Namibia; Canary & Cape Verde Islands

In Asia: Arabian Peninsula, mainly Oman and Yemen



In El Tofo, Chile, (Atacama Desert) about 1000 mm of fog drip are captured per $m^3$ per year ($1\ m^3/m^2 \times yr$)

- There are two-dimensional and three dimensional fog collectors
- Strong differences between the seasons
- Well suited for tree establishment on mountain slopes

- In Oman, during the monsoon season, up to 50 litres per $m^2$ per day were measured
- On Table Mountain, South Africa, 3300 mm / yr were captured.

Namibia

Syria

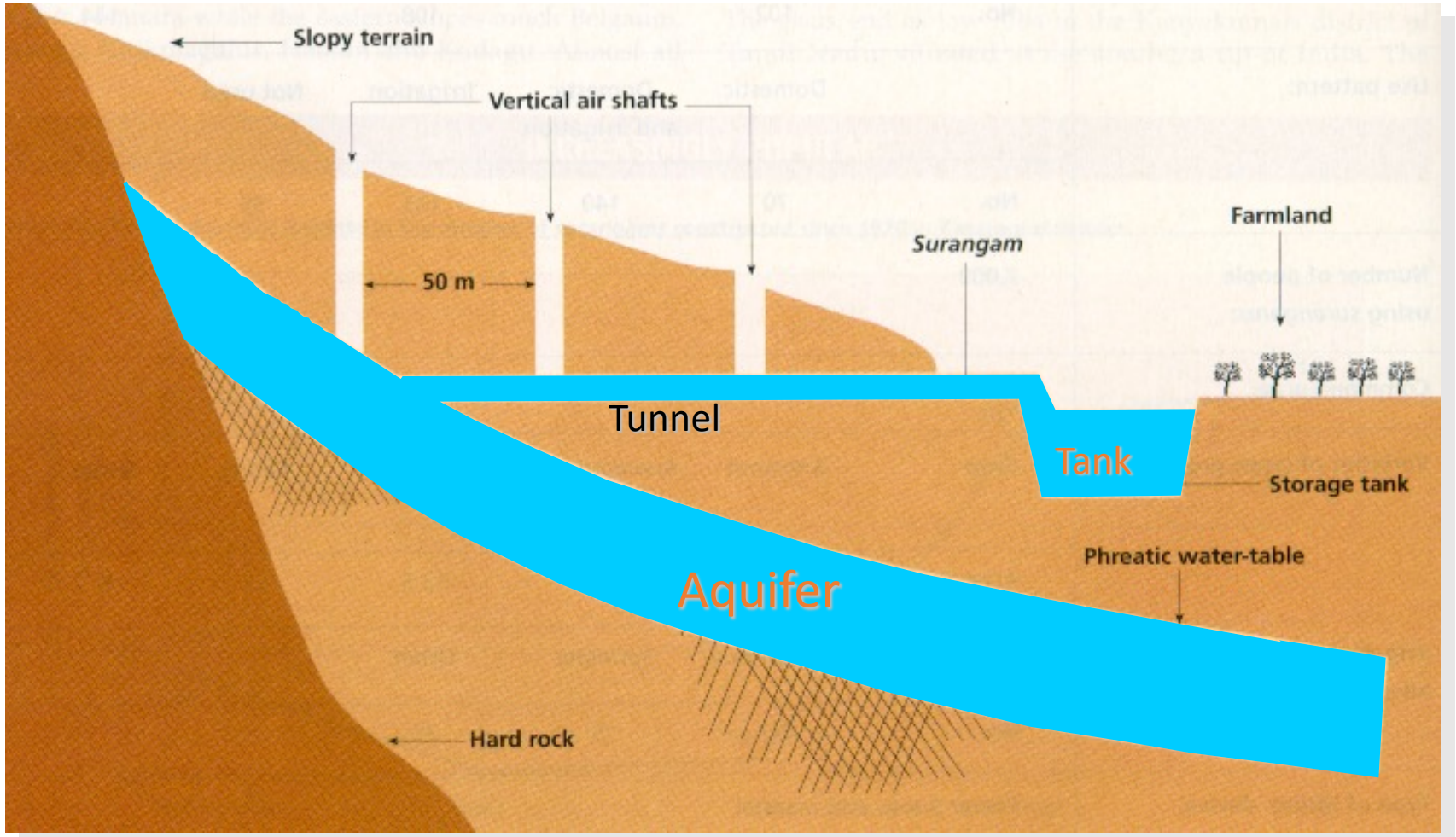
# GROUNDWATER HARVESTING

The term "Groundwater Harvesting" covers traditional and unconventional ways of groundwater extraction, e.g. by

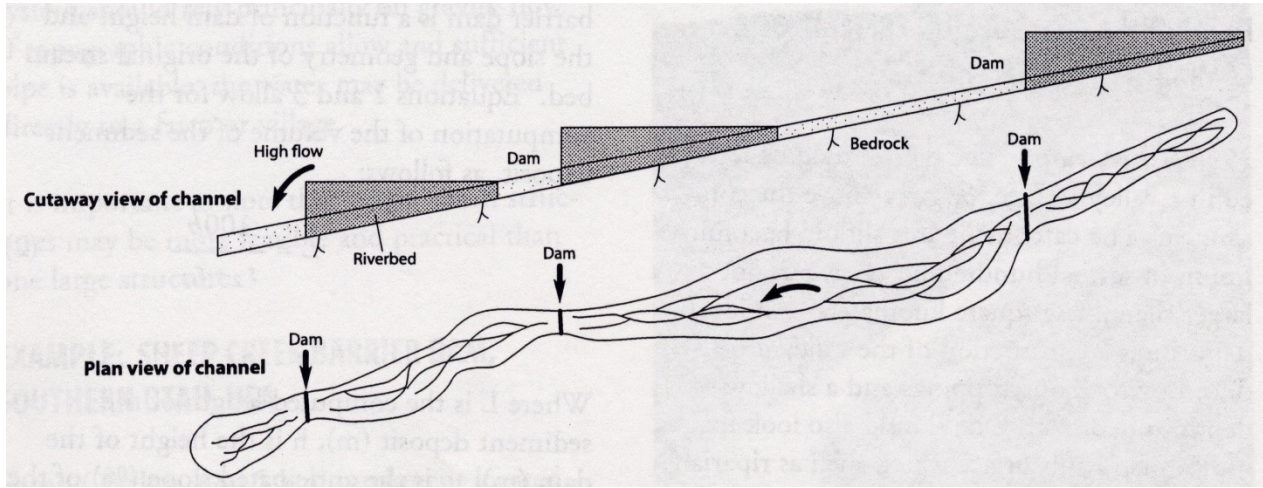
- 'Qanats', (using groundwater without lifting it)
- Groundwater Dams, (catching subterranean flow)
- Special Types of Wells (Horizontal Wells, Artesian Wells)

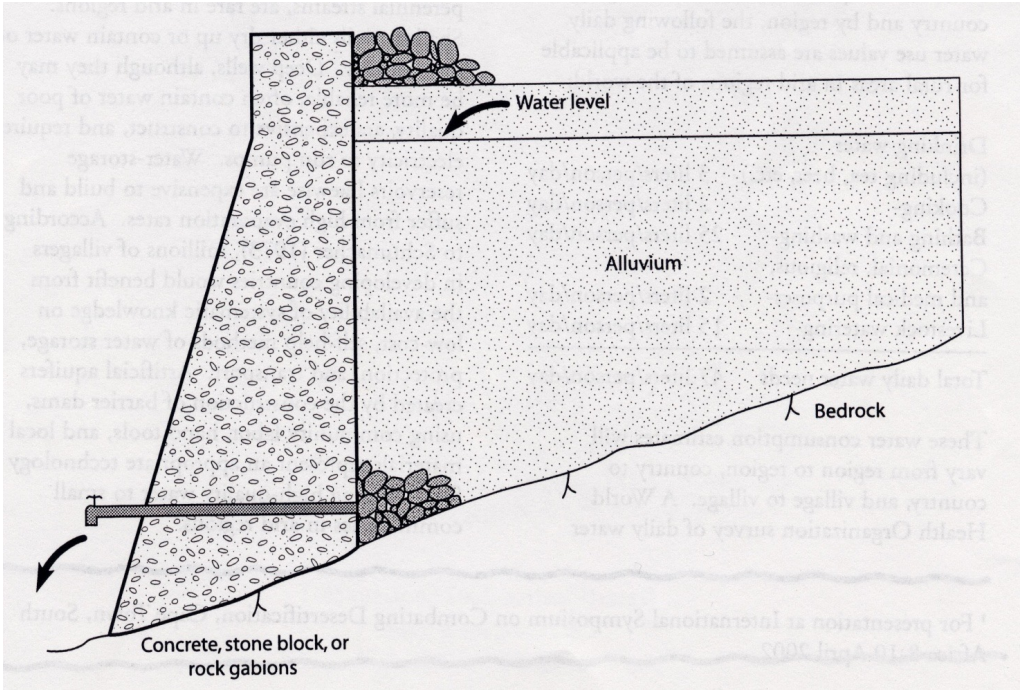
# GROUNDWATER HARVESTING

**QANATS** convey water by gravity to the ground surface

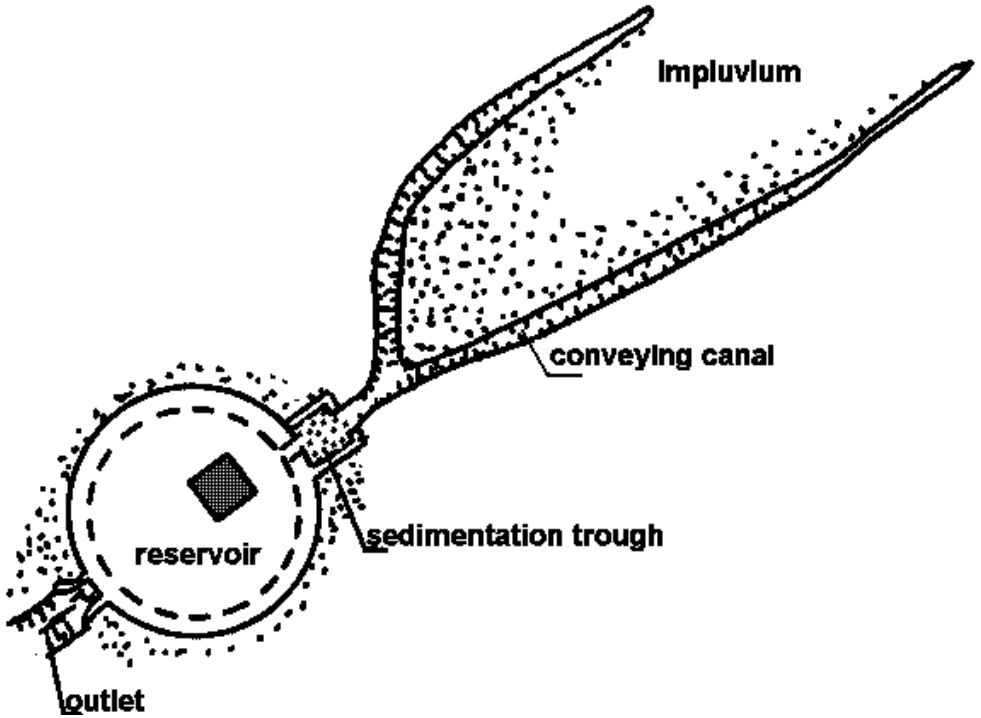



SOURCE: Agarwal & Narain : Dying Wisdom. State of India's Environment 4. New Delhi 1997


Dam
High flow
Dam
Bedrock
Dam
Cutaway view of channel
Riverbed
Dam
Dam
Plan view of channel

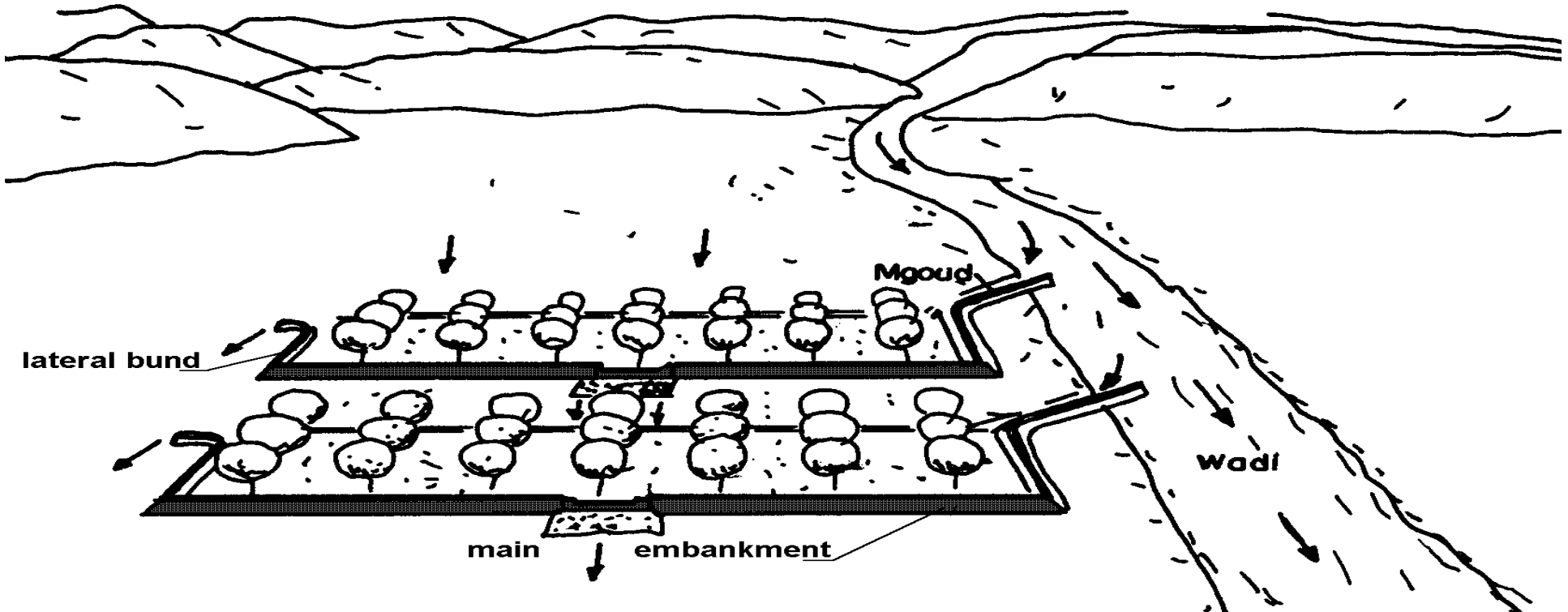

Water level
Alluvium
Bedrock
Concrete, stone block, or
rock gabions

Cisterns


Impluvium
conveying canal
reservoir
sedimentation trough
outlet

# Flood spreading / prevention

# Tabia on spreading system

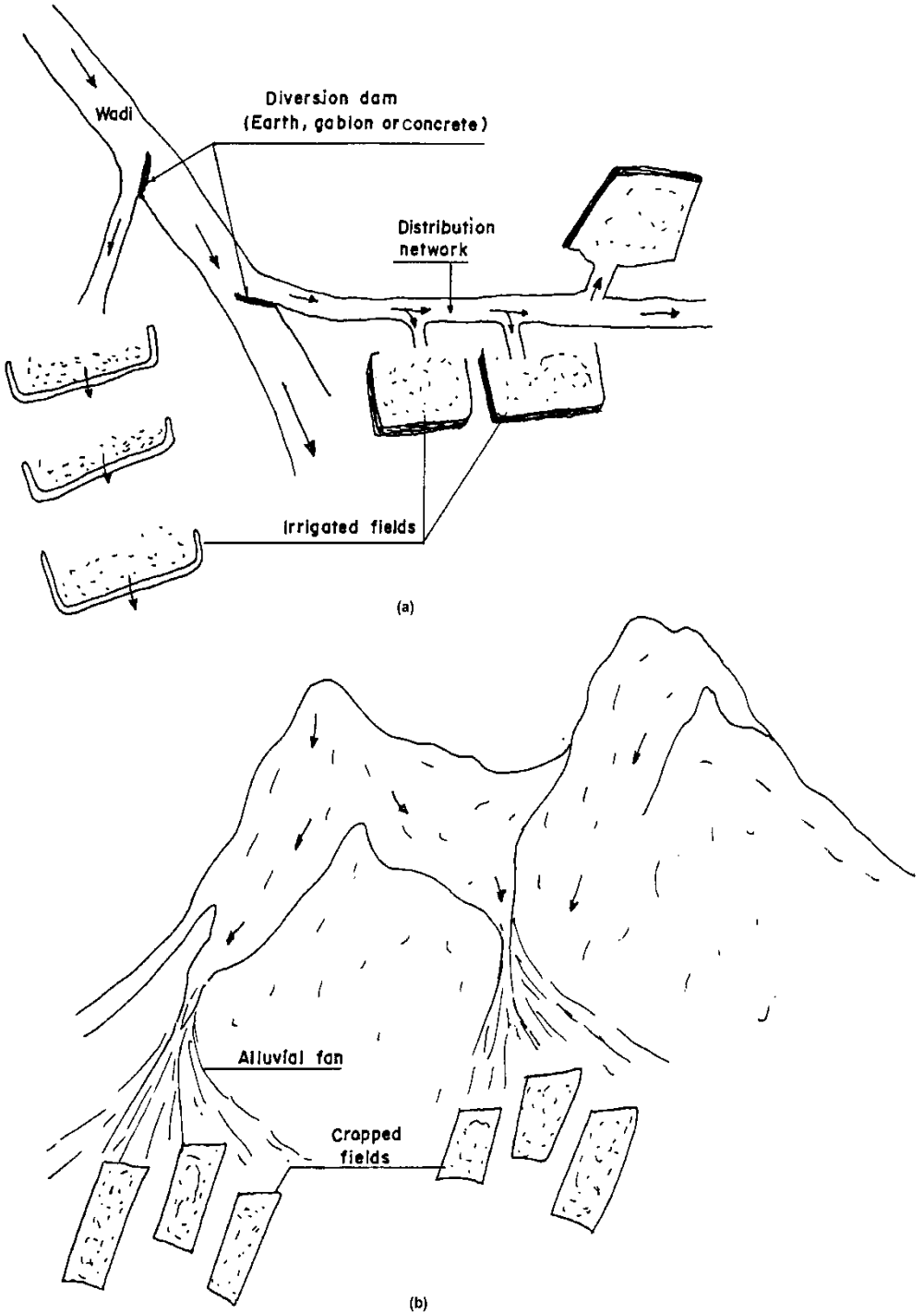


Tunisia

# Floodwater diversion & spreading

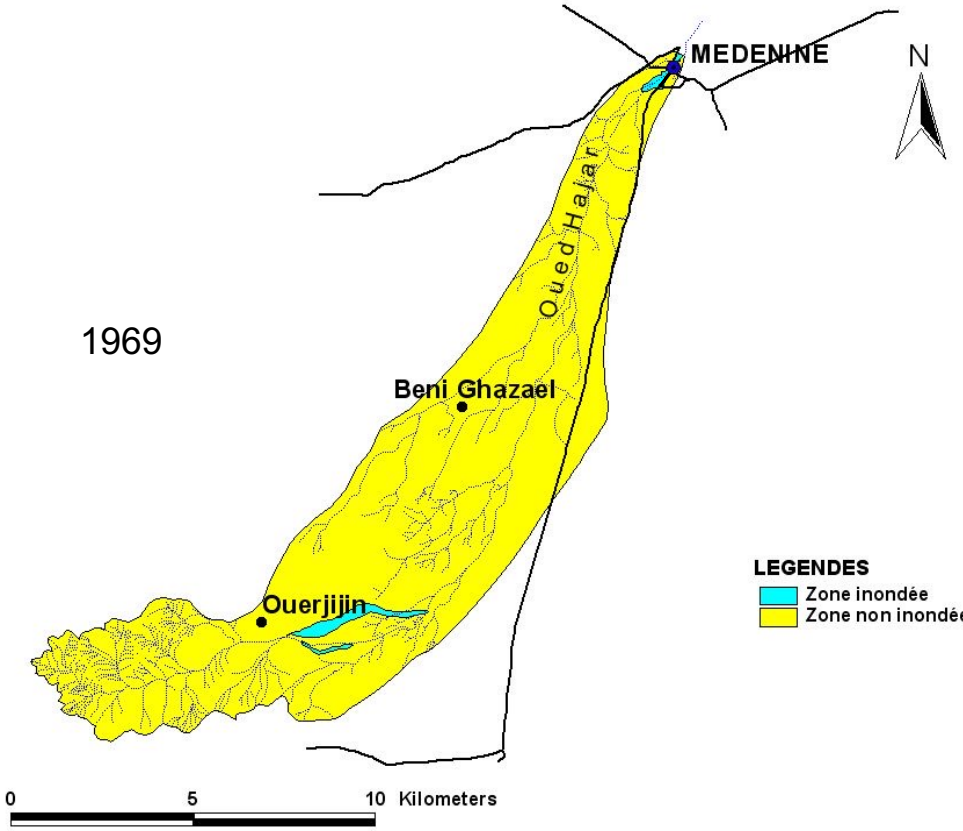
Canaries

Yemen




Flood spreading

# Flooding in Medenine, Tunisia










Chniter & Ouessar, 2006

# Landscaping/ ecotourism & cultural heritage

Matmata, Tunisia

Canary Island, Spain

Yemen

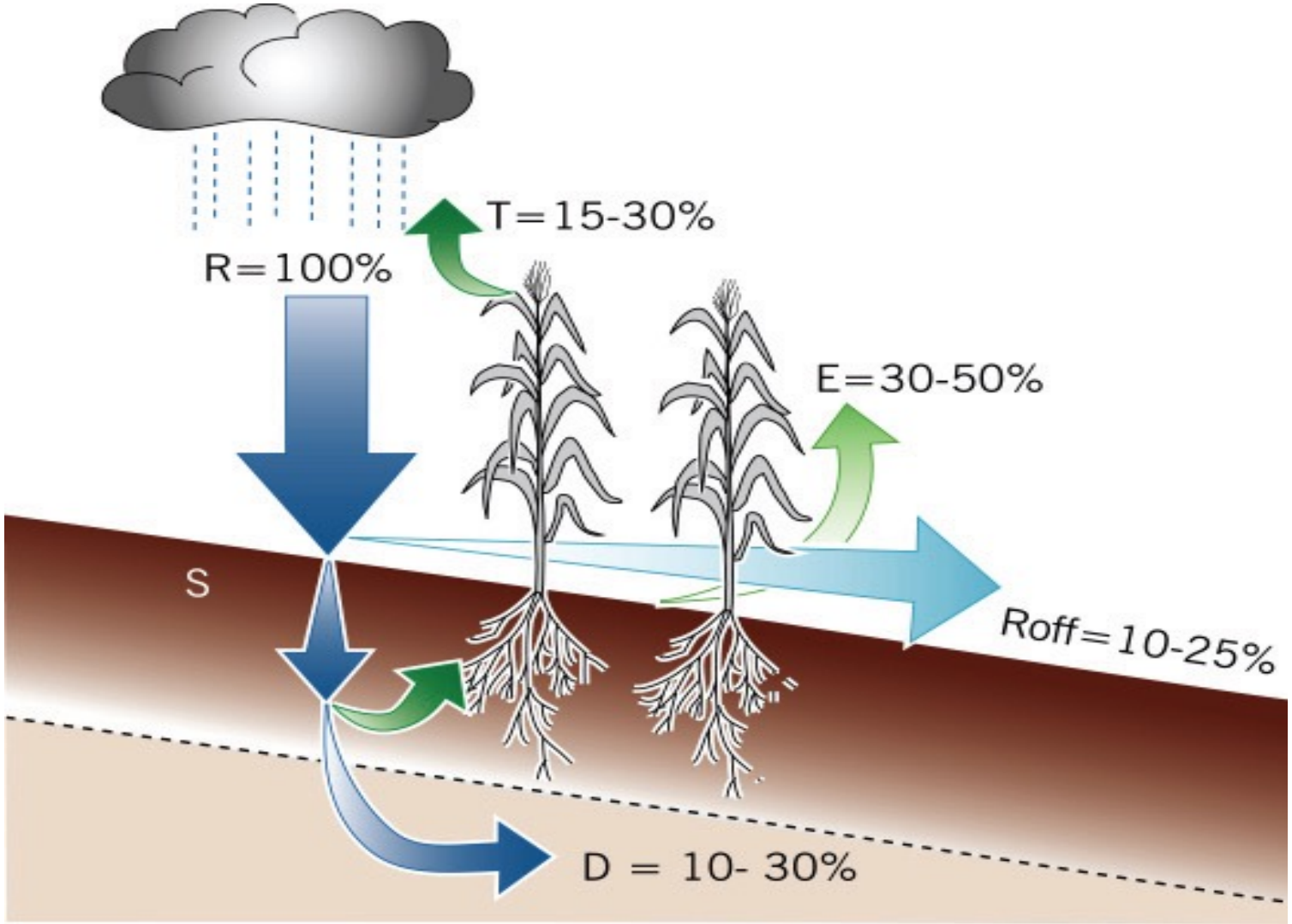
.... for afforestations

... and fruit tree cropping

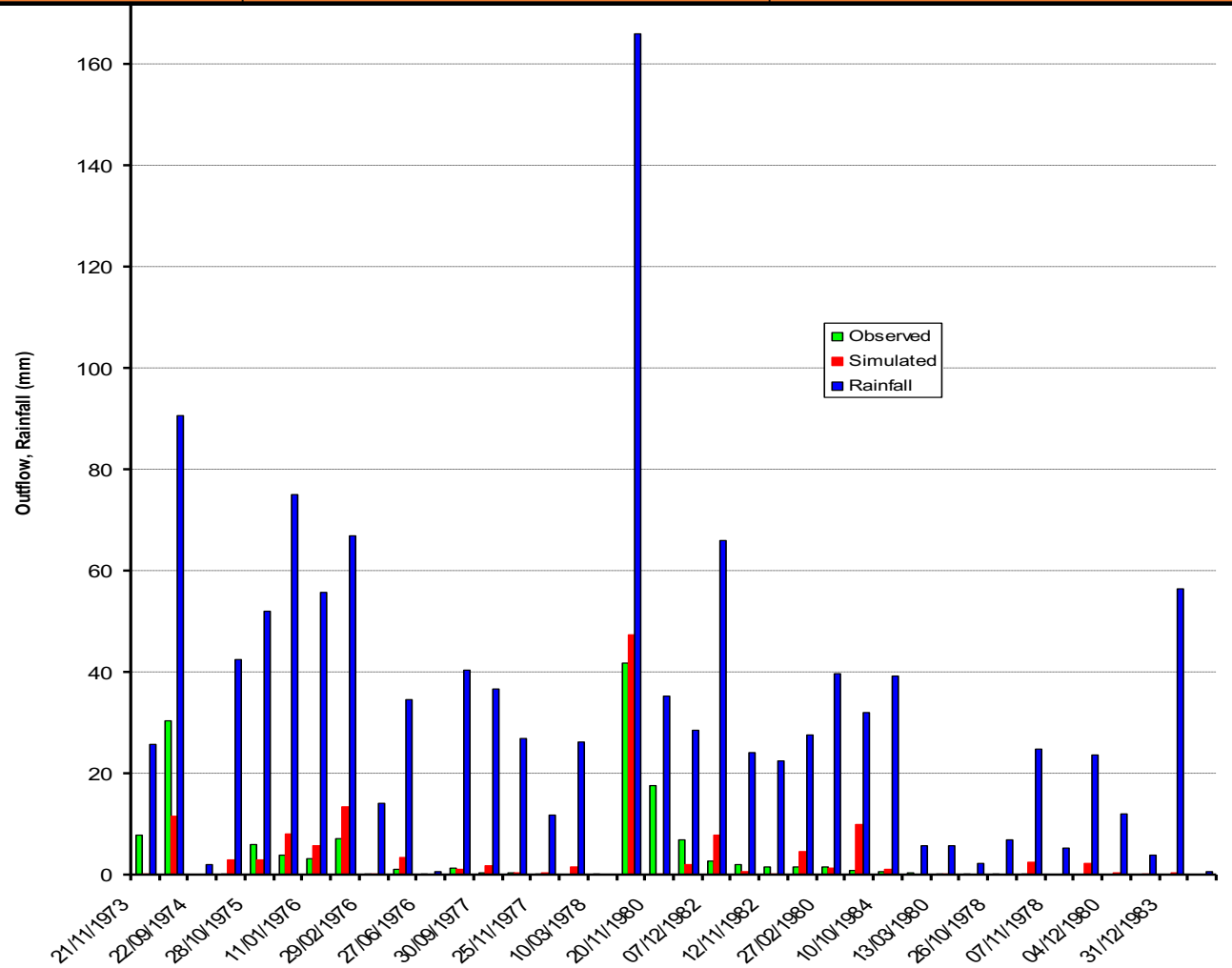
# *Integration of the Zammour site (jessour) in some international alternative tourism circuits*


مهرجان الزيتون الجبلي بشنني و الدويرات
أيام 25، 26 ديسمبر 2021
فكونوا فالموعد لإنجاح هدا العرس الثقافي في دورته الثانية
Douiret Tataouine photography

# Combined effects


T=15-30%
R=100%
E=30-50%
S
Roff=10-25%
D = 10- 30%

| | Calibration (1979-1985) | Validation (1973-1978) |
|---|---|---|
| $R^2$ | 0.77 | 0.76 |
| E | 0.73 | 0.43 |



# Land use evolution before and after project

| Landuse | Before project "1991" | | After project "2004" | | Changes (before/after) | |
|---|---|---|---|---|---|---|
| | ha | % (tot) | ha | % (tot) | ha | % |
| Halophyte ranges | 949.4 | 2.7 | 949.4 | 2.7 | 0.0 | 0.0 |
| Mountain ranges | 12409.4 | 35.4 | 12409.4 | 35.4 | 0.0 | 0.0 |
| Plain ranges | 7105.2 | 20.3 | 2827.1 | 8.1 | -4278.1 | -12.2 |
| Cereals | 3947.3 | 11.3 | 1806.7 | 5.2 | -2140.6 | -6.1 |
| Olives on jessour | 8275.3 | 23.6 | 8275.3 | 23.6 | 0.0 | 0.0 |
| Olives on tabias | 2380.3 | 6.8 | 8799.0 | 25.1 | 6418.7 | 18.3 |

# Scenarios

- SC0: It is a hypothetical scenario:  natural watershed, no water harvesting works nor crops.

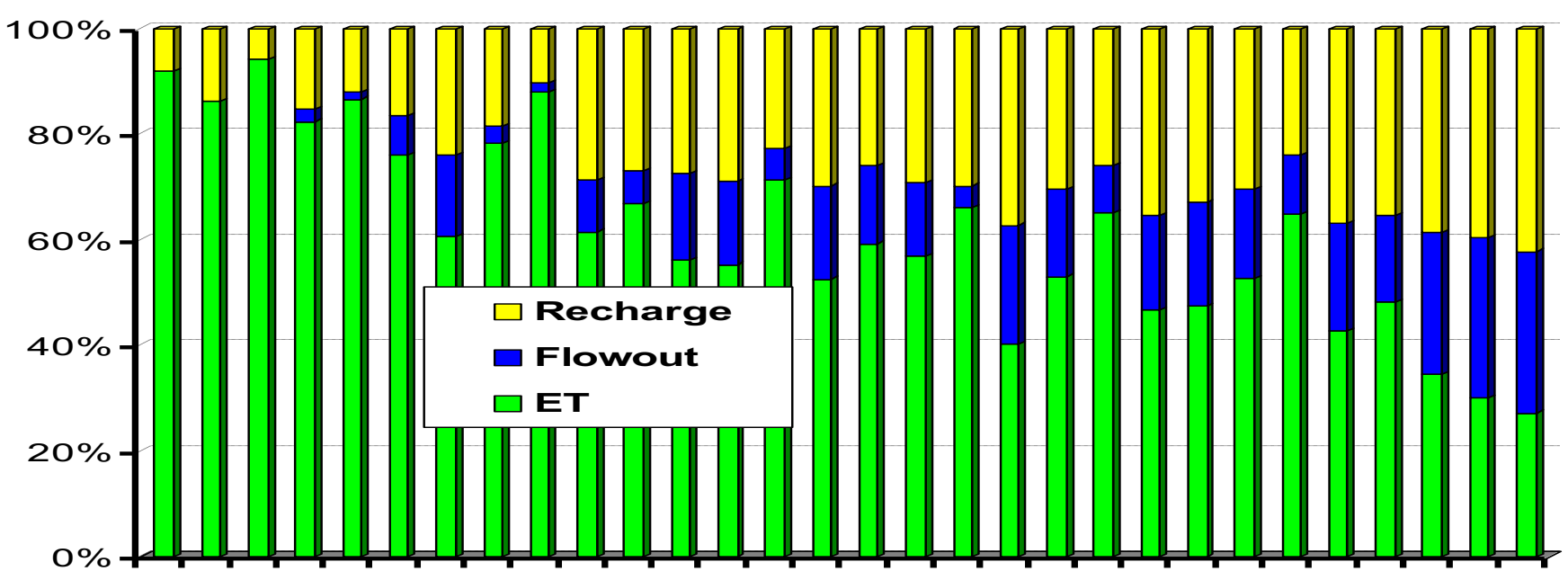
- SC1: water harvesting systems: *jessour* on the mountain area and *tabias* on the foothills.

- SC2: new *tabias* in the plain zone; gabion check dams for aquifer recharge and flood spreading.

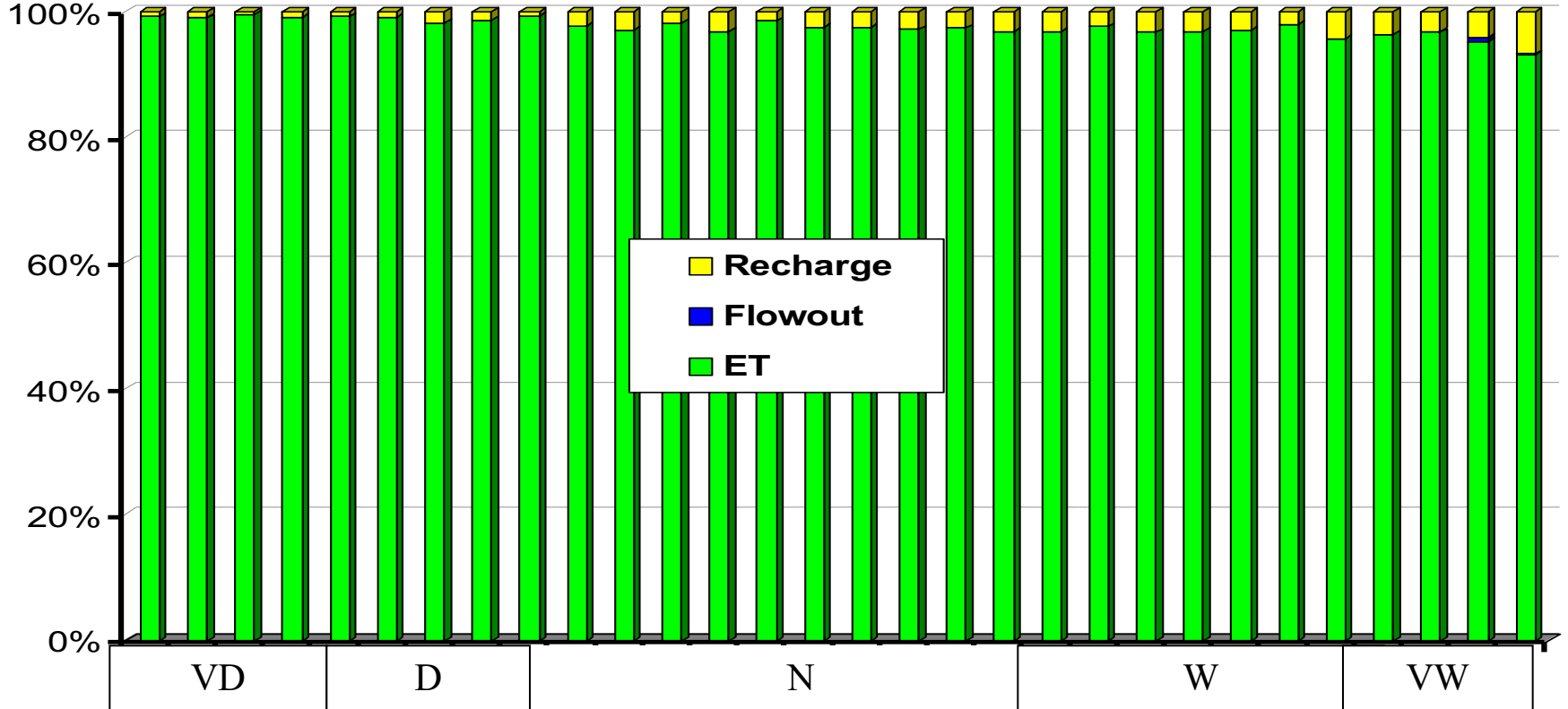
- SC3: The land use is similar to SC2 with partial silting up of the gabion check dams.

| | SC0 | | SC1 | | SC2 | | SC3 | |
|---|---|---|---|---|---|---|---|---|
| | mm | % | mm | % | mm | % | mm | % |
| **Rainfall** | 183.9 | - | 183.9 | - | 183.9 | - | 183.9 | - |
| **ET** | 107.0[a] | 58.2 | 147.2[b] | 80.1 | 150.9[b] | 82.0 | 150.9[b] | 82.0 |
| **Outflow** | 34.3[a] | 18.7 | 4.0[b] | 2.2 | 0.1[c] | 0.0 | 0.1[c] | 0.0 |
| **Perco** | 14.5[a] | 7.9 | 24.3[b] | 13.2 | 28.2[b] | 15.4 | 28.3[b] | 15.4 |
| **TLOSS** | 28.0[a] | 15.2 | 8.2[b] | 4.4 | 3.1[c] | 1.7 | 3.2[c] | 1.7 |
| **Seepage** | 0[a] | 0.0 | 0[a] | 0.0 | 1.1[b] | 0.6 | 0.9[b] | 0.5 |

SC0


100%
80%
60%
40%
20%
0%
Recharge
Flowout
ET

SC2


100%
80%
60%
40%
20%
0%
Recharge
Flowout
ET
VD
D
N
W
VW

# CONCLUSIONS

- Water harvesting techniques have been developed since antiquity to cope with climate variability in the dry areas,
- They played major role in the development of rainfed agriculture in addition of providing other ecosystem services,
- Silting up of the structures remains a major concern,
- However, accelerated exodus into cities would threaten the maintenance of those structures,
- Conflicts of interests (upstream/downstream users, main activity, etc.) need to be taken into account as an integrated management plan at watershed level,
- New tools (GIS, RS, modeling, etc.) offer major advantages/capabilities for the implementation and assessment of WH projects/works,
- With the prospect of CC, those systems/techniques would be more useful. Therefore, they need to be well considered in the national/regional strategies for adaptation with CC,

# Thank you


*This is an olive tree growing in a dry environment (rainfall: 160 mm/year ) …….*