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Water harvesting in arid and semi-arid regions: soil physical and soil hydrological aspects.

Donald Gabriels

Dept. Soil Management
Ghent University
Belgium

Outline of the presentation

1. Overview of irrigation and water harvesting systems in dryland farming
2. Case study: southern Tunisia
3. Case study: loess plateau of North China
4. Case study: Cape Verde
5. Case study: Chile

Part 1: irrigation and water harvesting systems in dryland farming

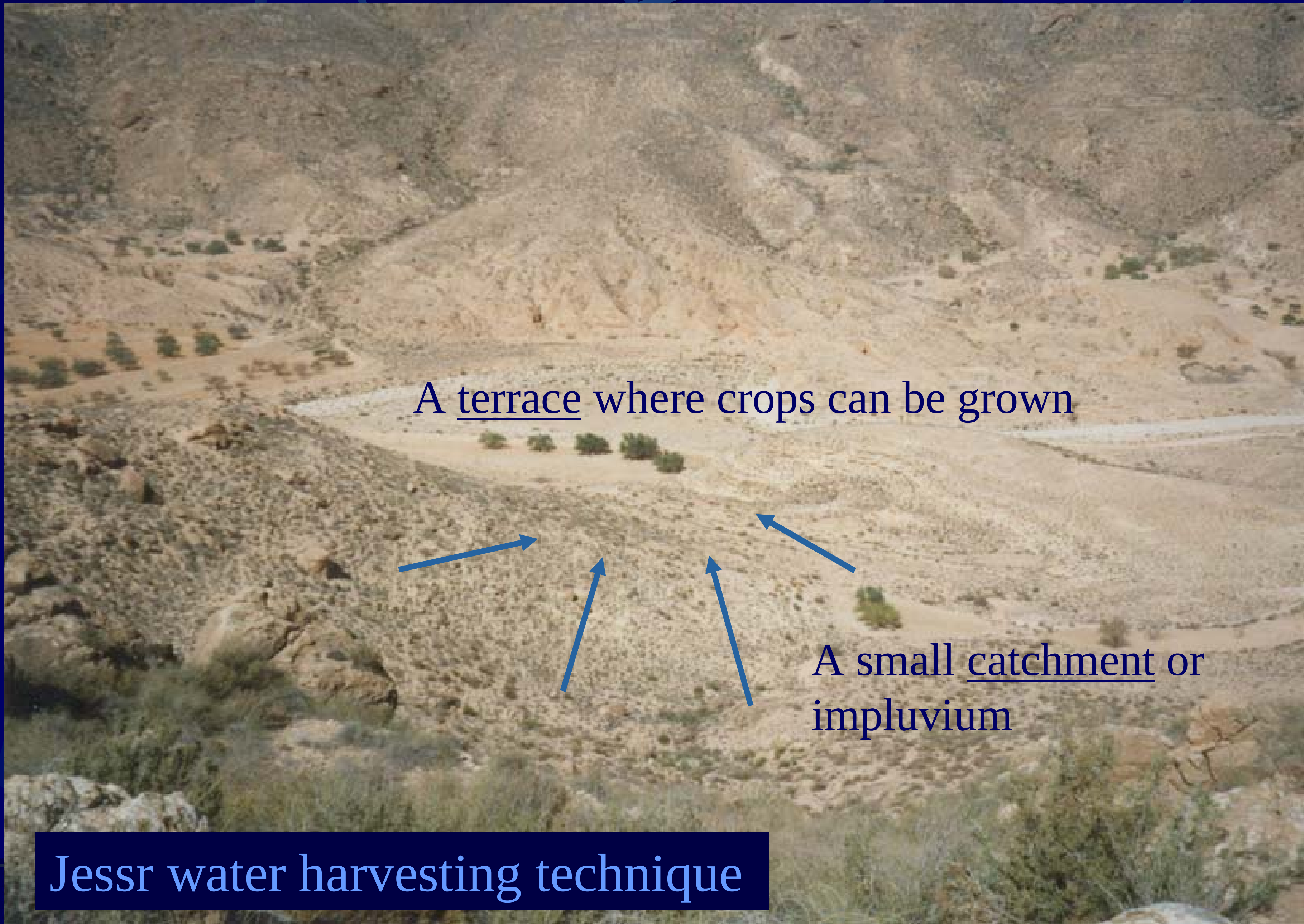
Part 2: Rainfed farming in southern Tunisia using water harvesting techniques

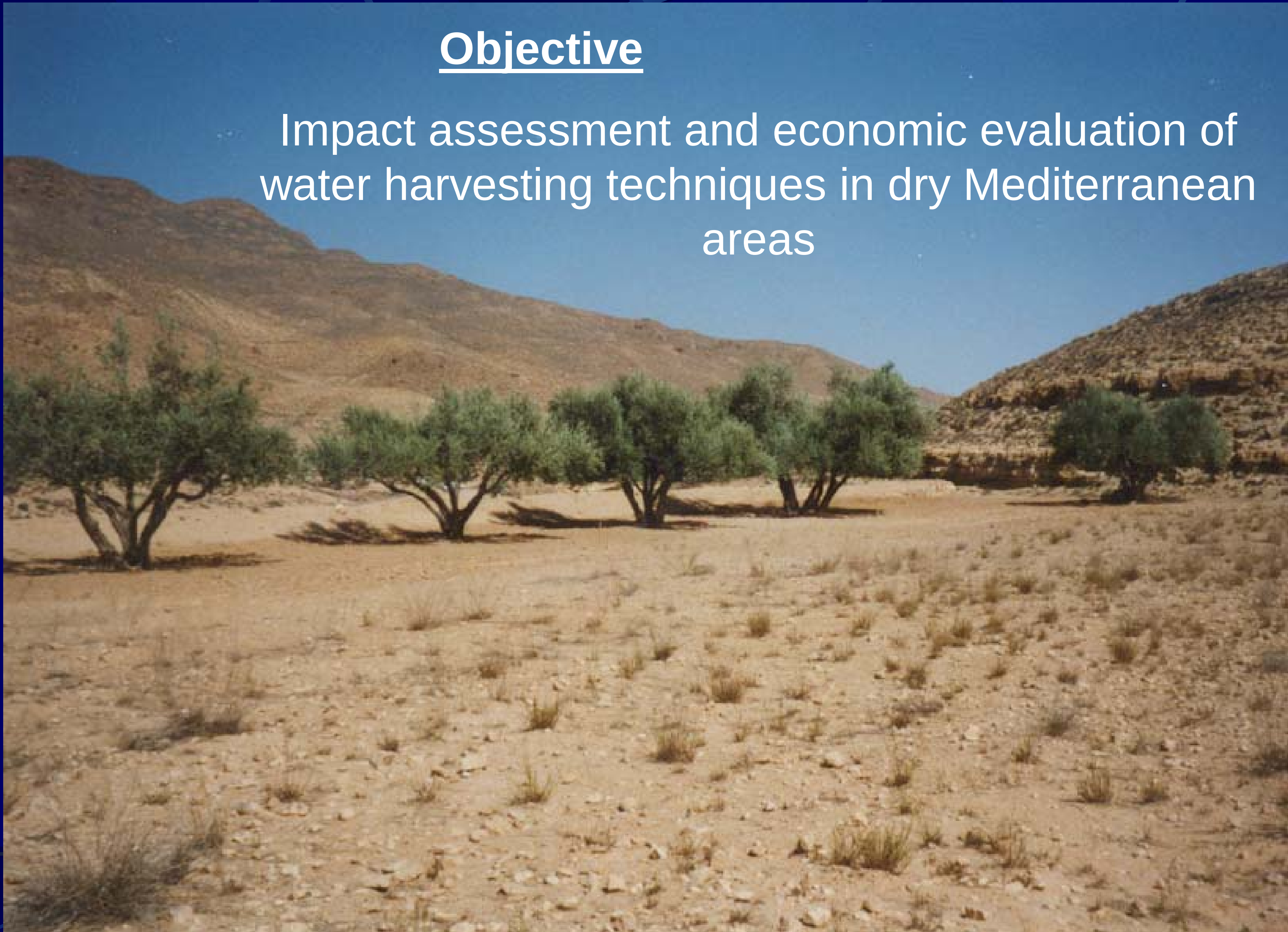
WAHIA-project

Wa**ter** **H**arvesting **I**mpact **A**ssessment

in Zeus-Koutine, Tunisia

Rainfed farming in southern Tunisia using water harvesting techniques





Objective

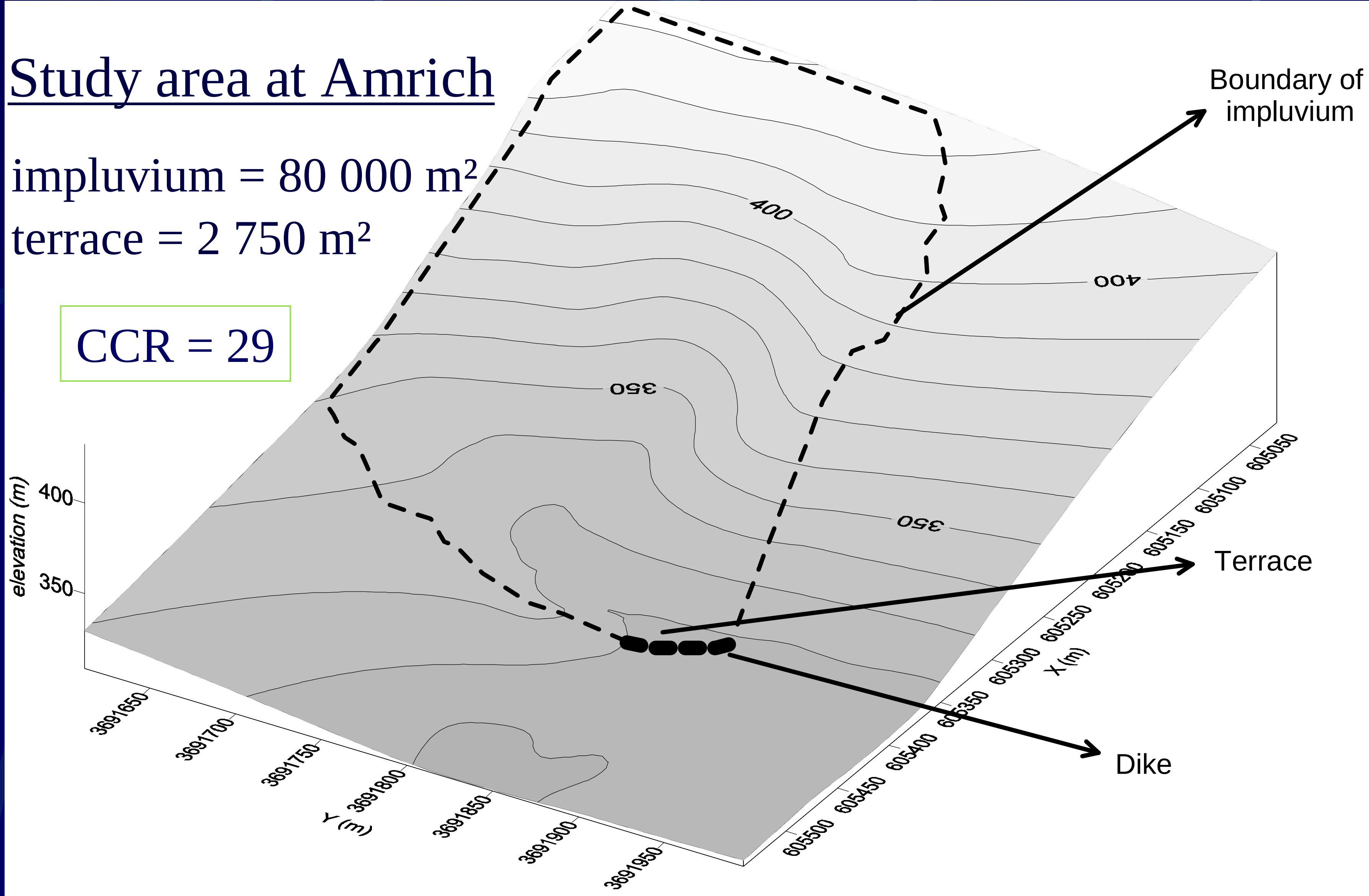
Impact assessment and economic evaluation of water harvesting techniques in dry Mediterranean areas

Study area at Amrich

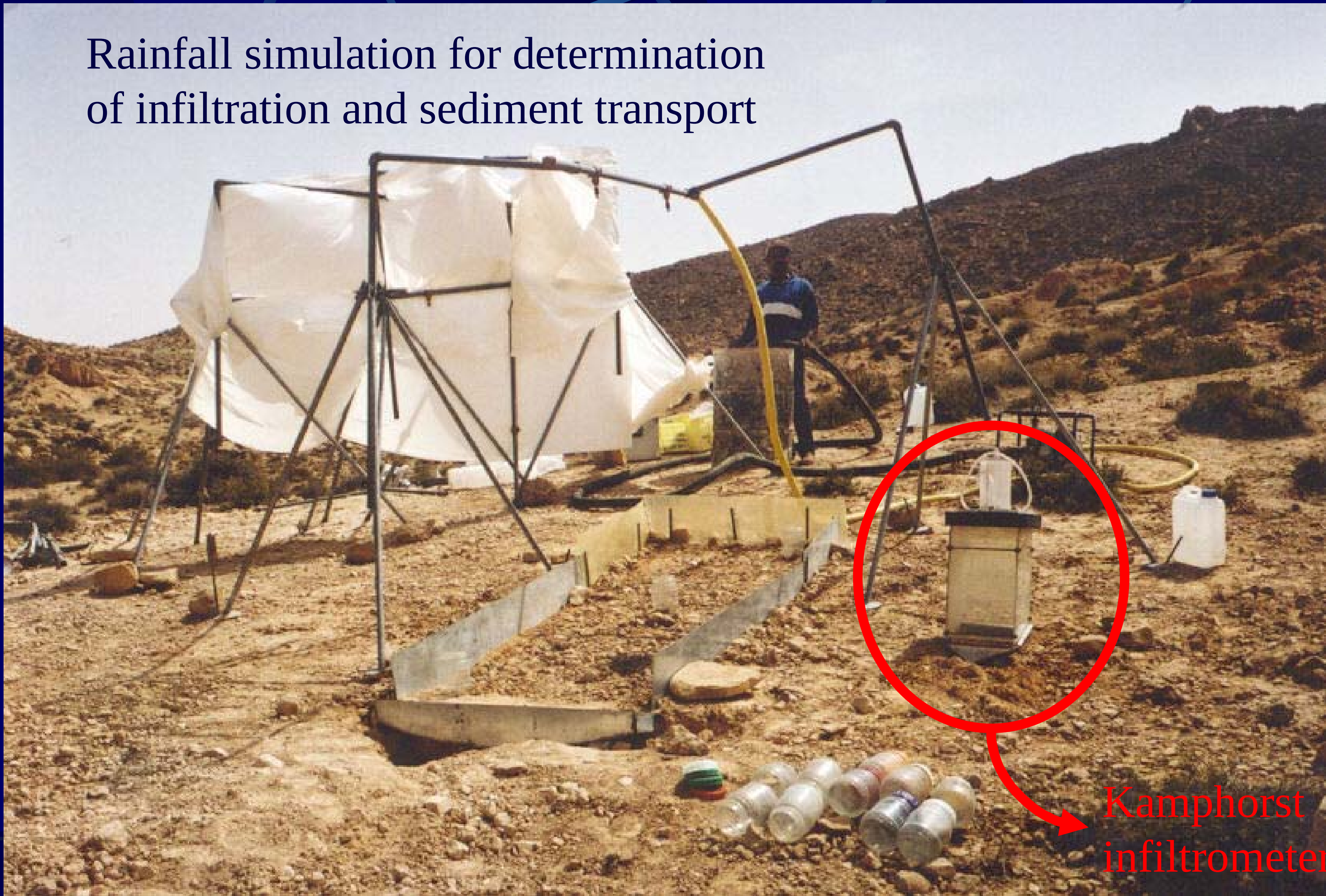
impluvium = 80 000 m²

terrace = 2 750 m²

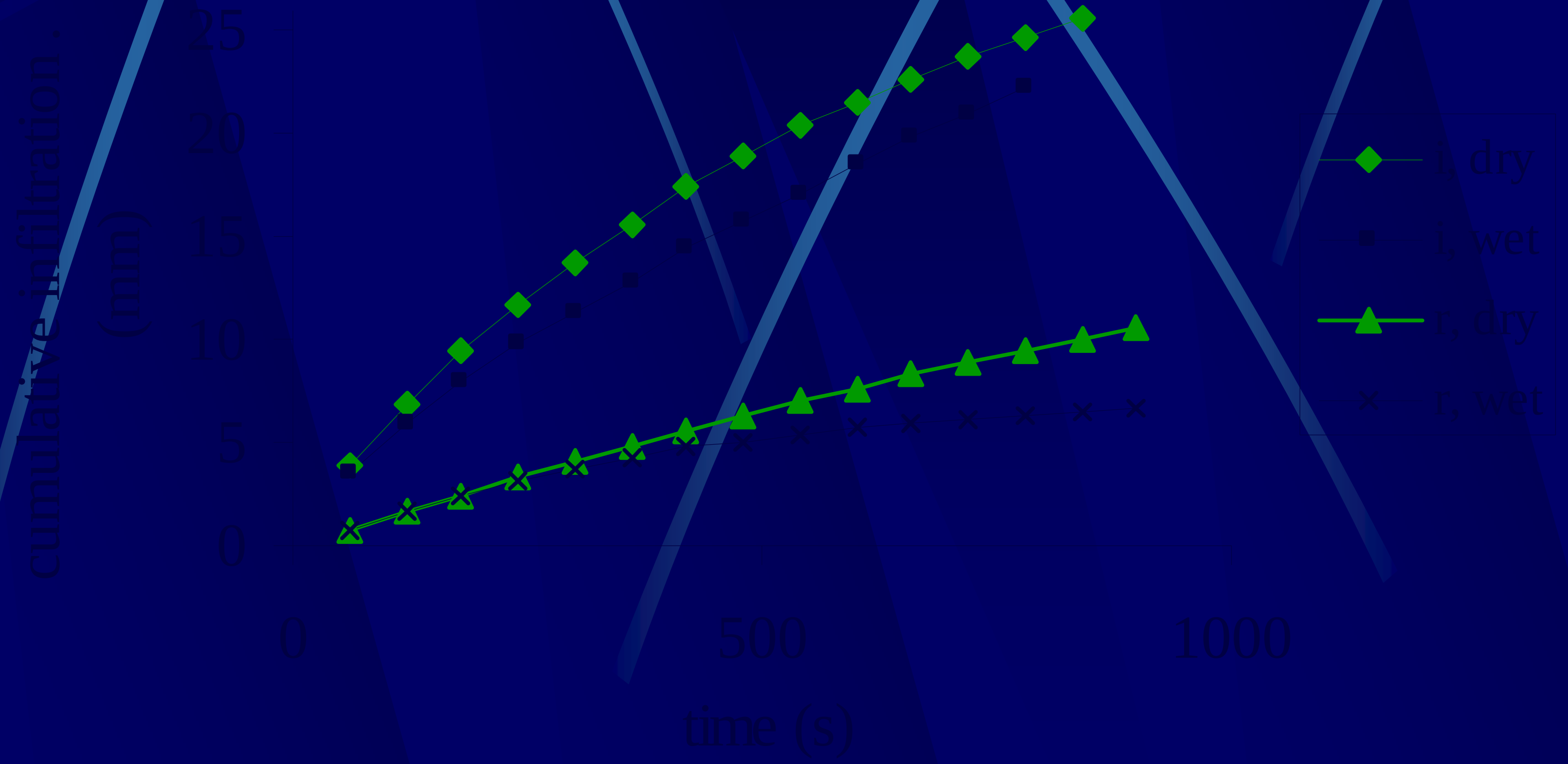
CCR = 29



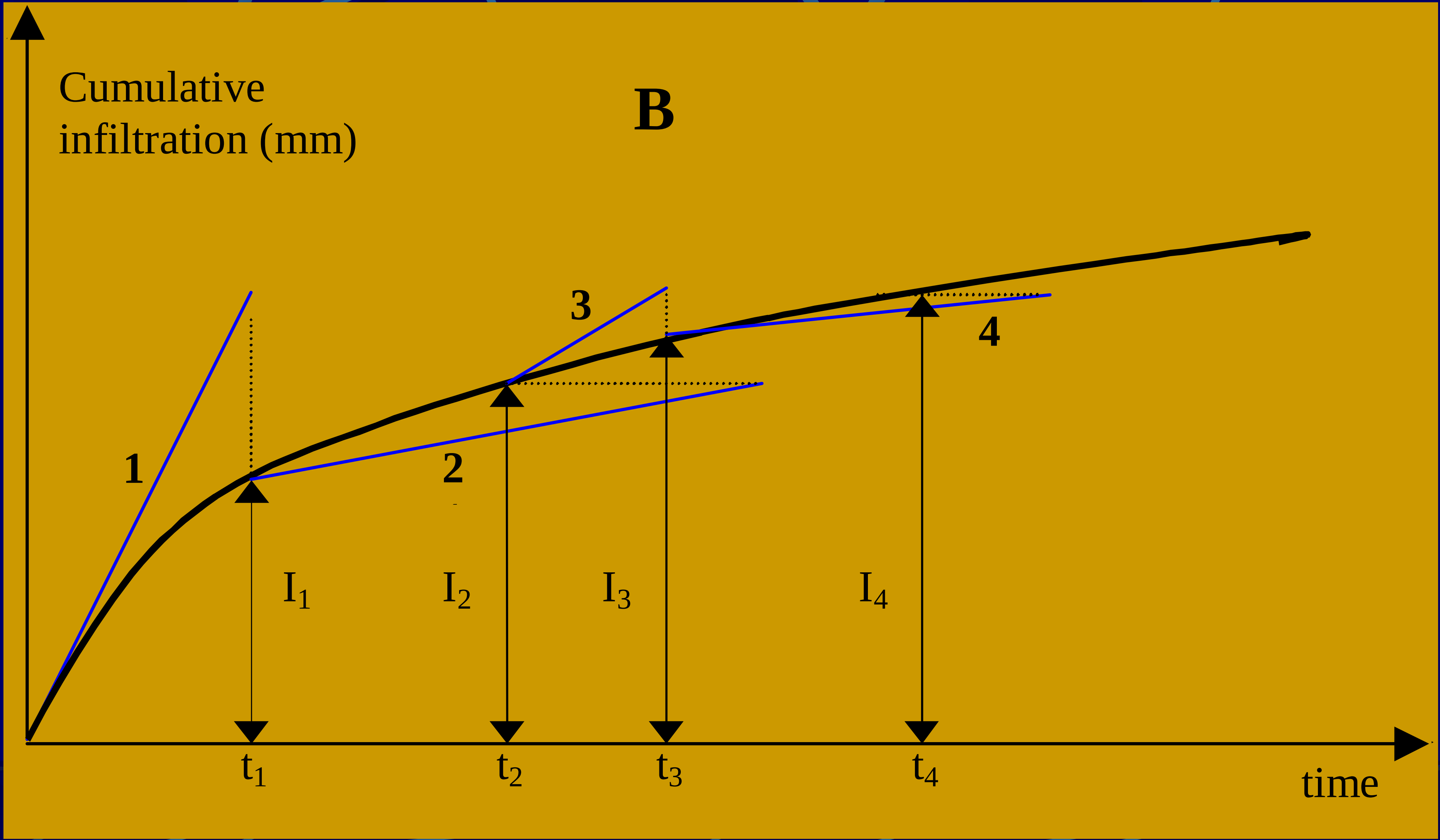
Rainfed farming in southern Tunisia using water harvesting techniques



Soil infiltration characteristic for an initially dry and an initially wet soil, using the Kamphorst infiltrometer (i) and the rainfall simulator (r)



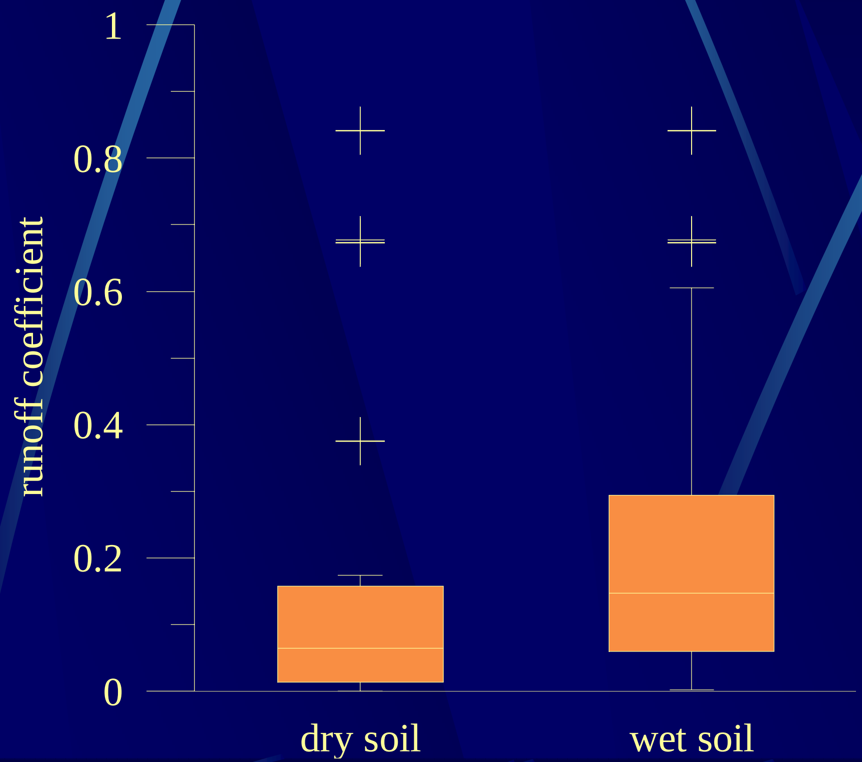
Runoff coefficients can be calculated using the TCA method



Rainfall station at Chouamekh:
102 rainfall events (period April 1998 – August 2001)

→ based on the TCA method: 25 runoff events

runoff coefficients:



	average	median
initially dry soil	0.153	0.064
initially wet soil	0.217	0.147

Estimating the runoff and erosion at the study area using the stream power concept

$$\omega = \rho \cdot g \cdot s \cdot q$$

ρ = density of water (g cm^{-1})
g = gravitational constant (cm s^{-1})
s = slope gradient (m m^{-1})
q = unit discharge of runoff (cm^3 cm^{-1} s^{-1})

A relation between the stream power and the sediment load can be established using rainfall simulations

$$q_s = 6 \cdot 10^{-6} \cdot \omega^{1.417}$$

q_s = unit sediment load (g cm^{-1} s^{-1})

Estimating the runoff and erosion at the study area using the TCA and the stream power concept

Date	Total rainfall (mm)	Average rainfall intensity (mm h^{-1})	Harvested water (m^3)	Harvested sediment (kg)
21/10/1998	77.3	77	4315	50444
26/11/1999	40.0	**1.8**	0	0
27/04/1998	25.5	6.4	55	92
21/10/1998	24.9	60	1076	10216
25/05/2000	12.5	2.3	5	2
24/09/1998	10.4	**14.5**	100	378

→ Meinzinger (2001)

$$CCR = \frac{WR - P}{C \cdot P}$$

WR annual amount of water needed for the crop (mm)
P average annual rainfall (mm)
C average annual runoff coefficient (-)

→ Amrich:
- C = 0.15 (mean)
- P = 235
- WR = 500 (olive trees)

$$CCR = \frac{500 - 235}{0.15 \cdot 235} = 7.5$$

↔ Actual CCR = 29 → P = 93 mm

In 97% of the years the minimum requirements are met

→ Amrich:
- C = 0.064 (median)

$$CCR = \frac{500 - 235}{0.064 \cdot 235} = 17.6$$

↔ Actual CCR = 29 → P = 175 mm

In 64% of the years the minimum requirements are met

Scenario-analysis of the impact of water harvesting on evapotranspiration of olive trees

The water balance of the terrace of the Amrich jessr was calculated for 3 hydrologic years and 2 scenarios

- Sept 1998 – Aug 1999: 325.7 mm rainfall (wet year)
- Sept 1999 – Aug 2000: 146.5 mm rainfall (dry year)
- Sept 2000 – Aug 2001: 11.5 mm rainfall (extremely dry year)

- Scenario 1: no runoff from the impluvium
- Scenario 2: calculated runoff from the impluvium based on TCA and the measured infiltration characteristic on a dry soil

Water balance equation

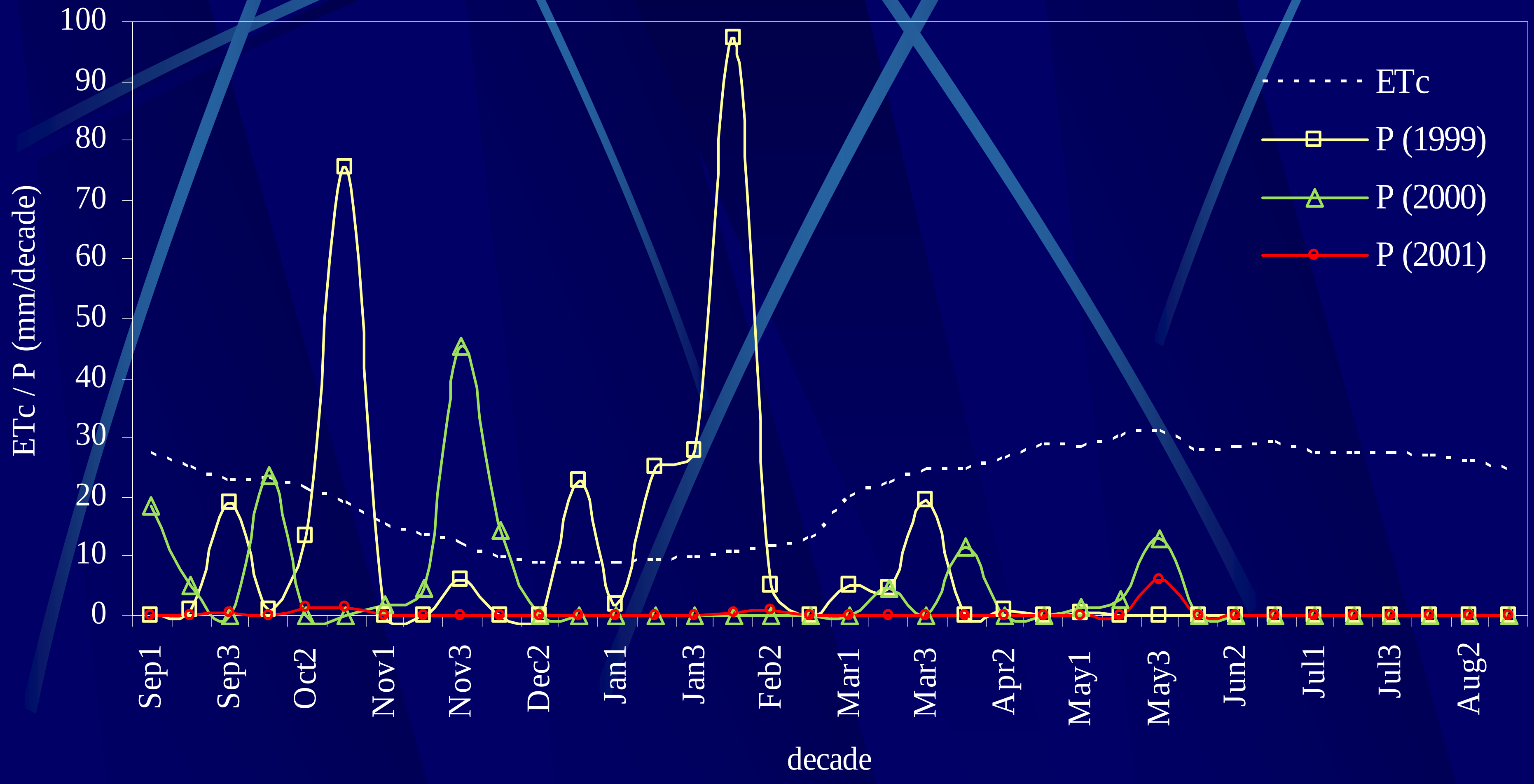
$$\Delta S = P + I - ET - R - D + L_i - L_o$$

- P: continuous rainfall data (tipping bucket: accuracy of 0.1 mm) of the weather station at Chouamekh
- I: calculated amount of runoff from impluvium
- ET: based on Penman-Monteith method (using climatic data of Medenine), crop coefficient (kc) and available water fraction (p)

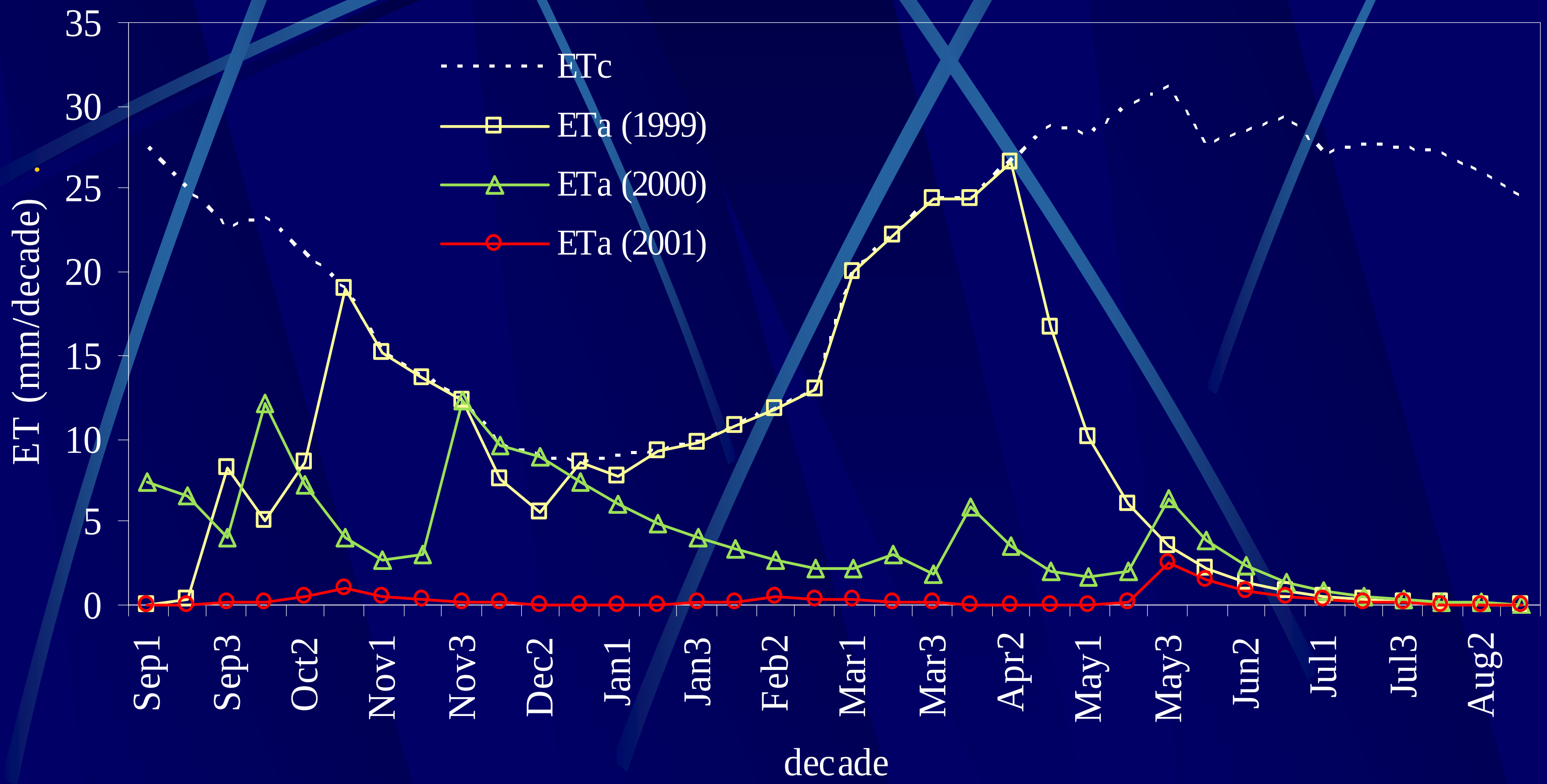
Assumptions: R, D, L_i and L_o = 0

maximum water level on the terrace = 200 mm (because of height of spillway)

Maximum crop evapotranspiration (ETc) and total rainfall (P) per decade of days



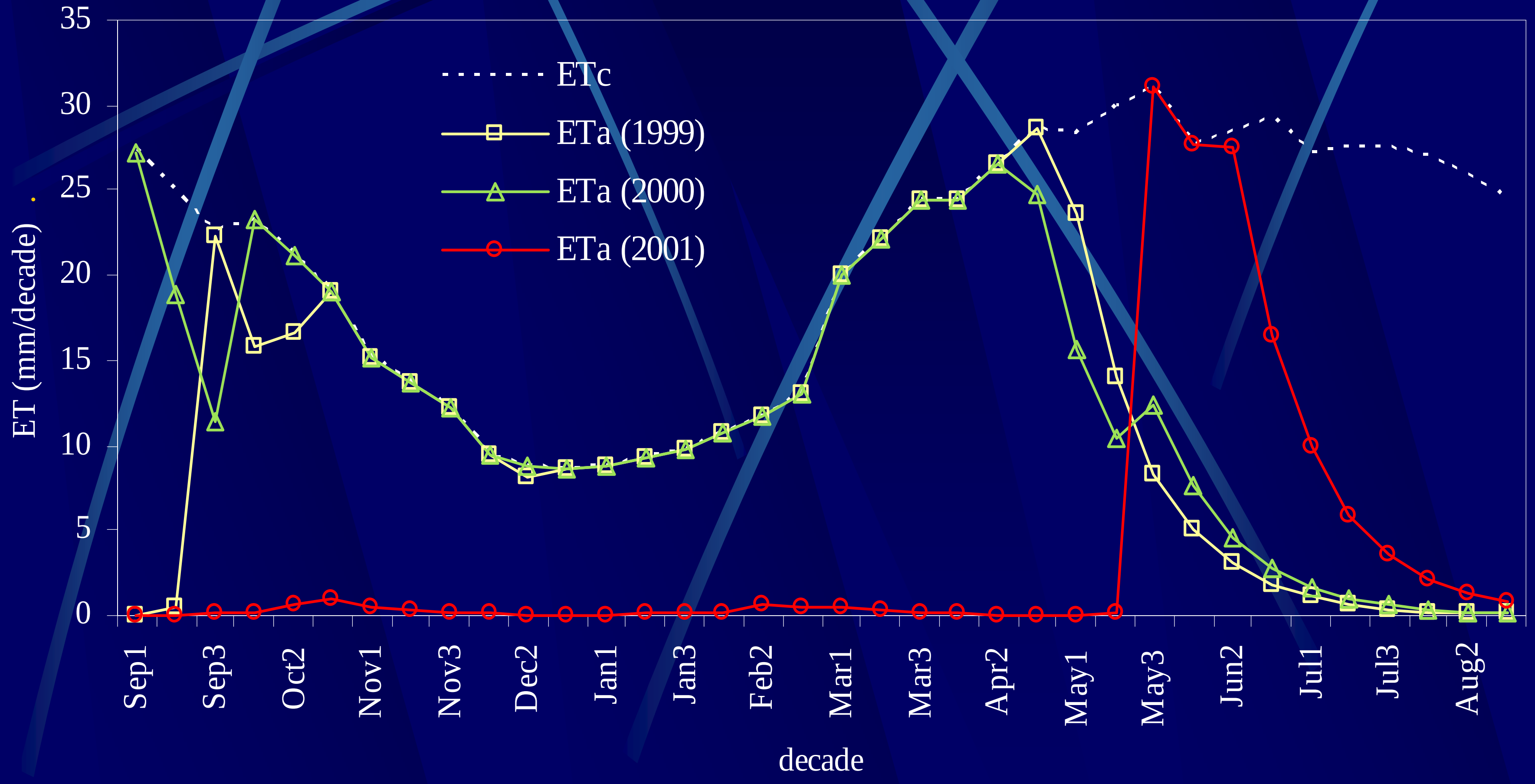
Maximum crop evapotranspiration (ETc) and actual evapotranspiration (ETa) per decade (scenario 1: no water harvesting)



→ During dry years (2000 and 2001) Eta < Etc during most months

⇒ impact on olive yield

Maximum crop evapotranspiration (ETc) and actual evapotranspiration (ETa) per decade (scenario 2: water harvested from impluvium)



→ During a dry year (2000) Eta = Etc during most months

Conclusions

- Estimation of the optimal CCR for crop production depends to a large extent on the estimated runoff coefficient.
- Based on a water balance study it was found that the jessr has a large beneficial impact on water availability during dry years, but a rather minor impact during wet years

Ongoing research

- Laboratory experiments to determine the percolation rate into infiltration pits

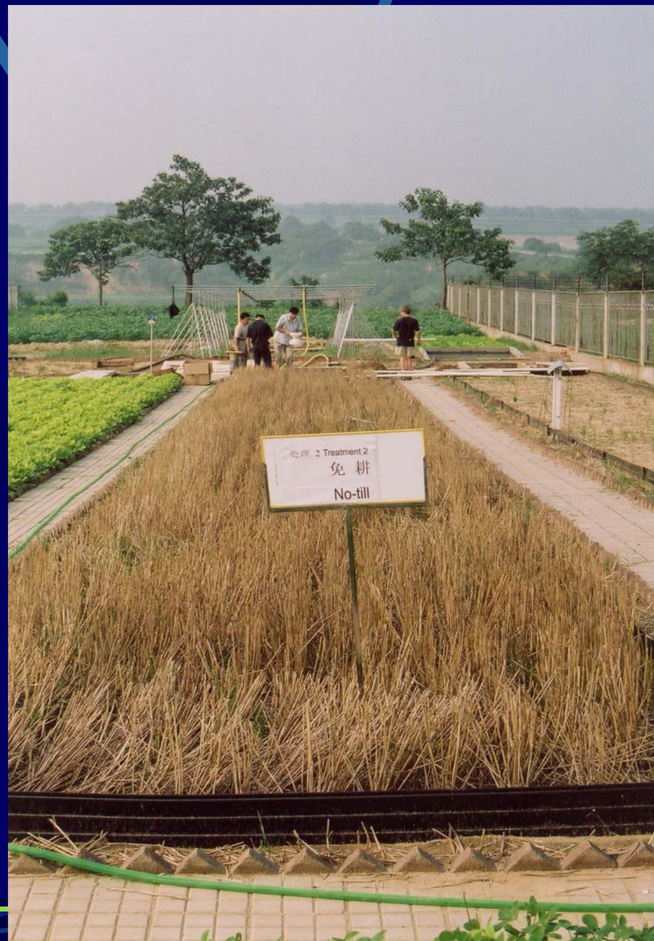
- Preliminary results indicate that the percolation rate decreases very fast due to blocking of the gravel filter by sediment

Part 3: Effect of tillage on the soil moisture balance in the loess plateau of China

The effect of tillage on the soil moisture balance: a case study on the loess plateau of China

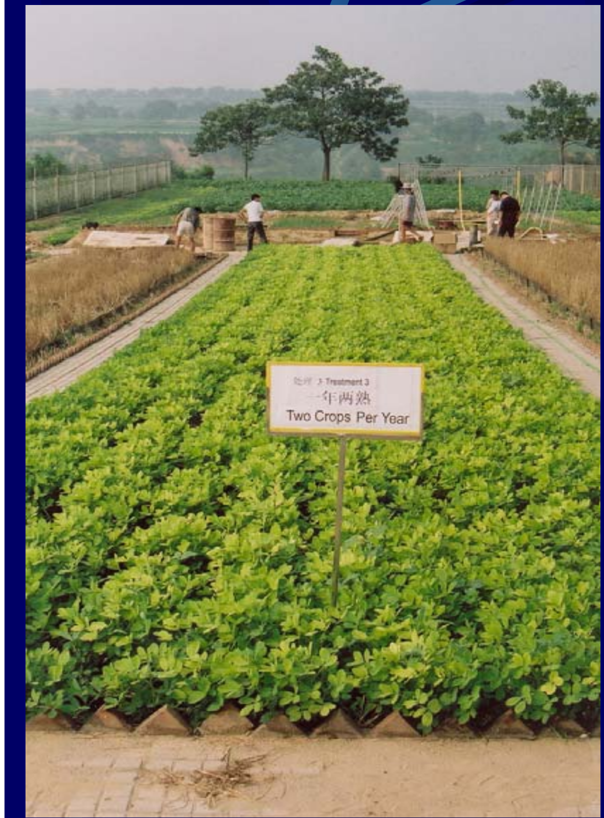
Tillage practices

•Reduced tillage RT



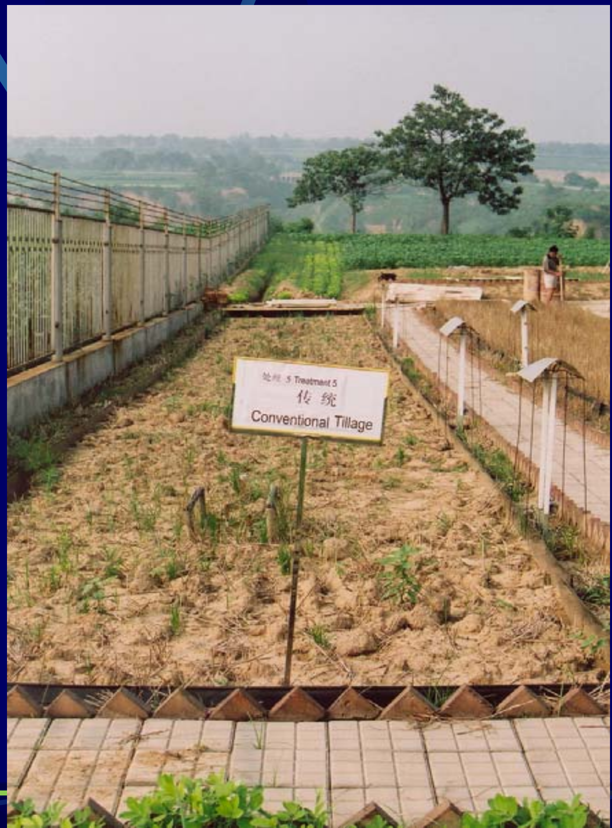
•No till NT

Tillage practices



•Two crops per year 2C

•Subsoiling SS



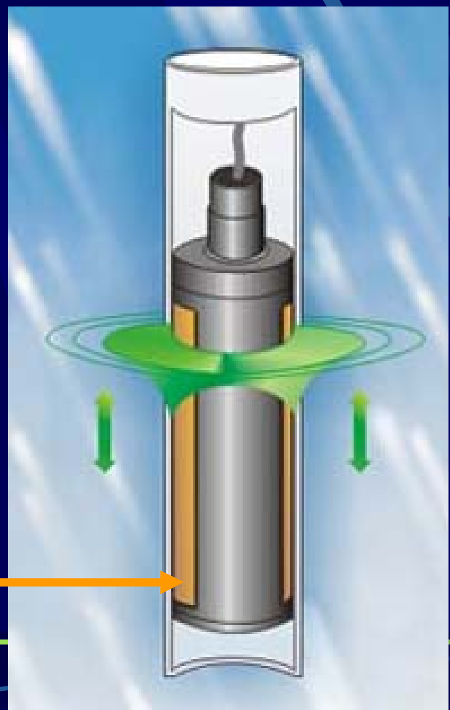
•Conventional tillage CT

Laboratory rainfall simulations with different straw covers (0, 25, 50 and 75 %)

The effect of tillage on the soil moisture balance: a case study on the loess plateau of China

Water balance equation

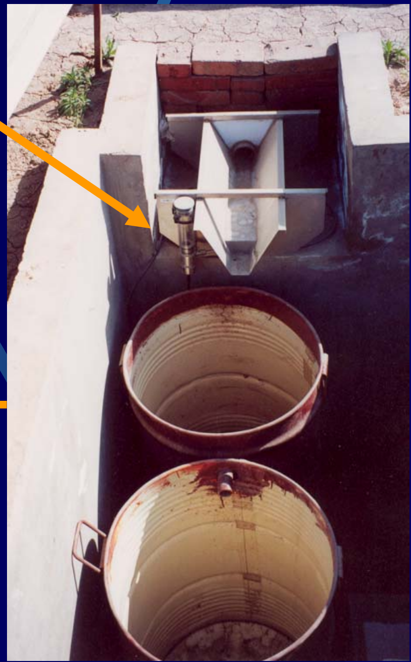
$$\Delta S = P + I - ET - R - D + L_i - L_o$$



Trime-FM3-Tube-probe (TDR)

Water balance equation

$$\Delta S = P + I - ET - R - D + L_i - L_o$$



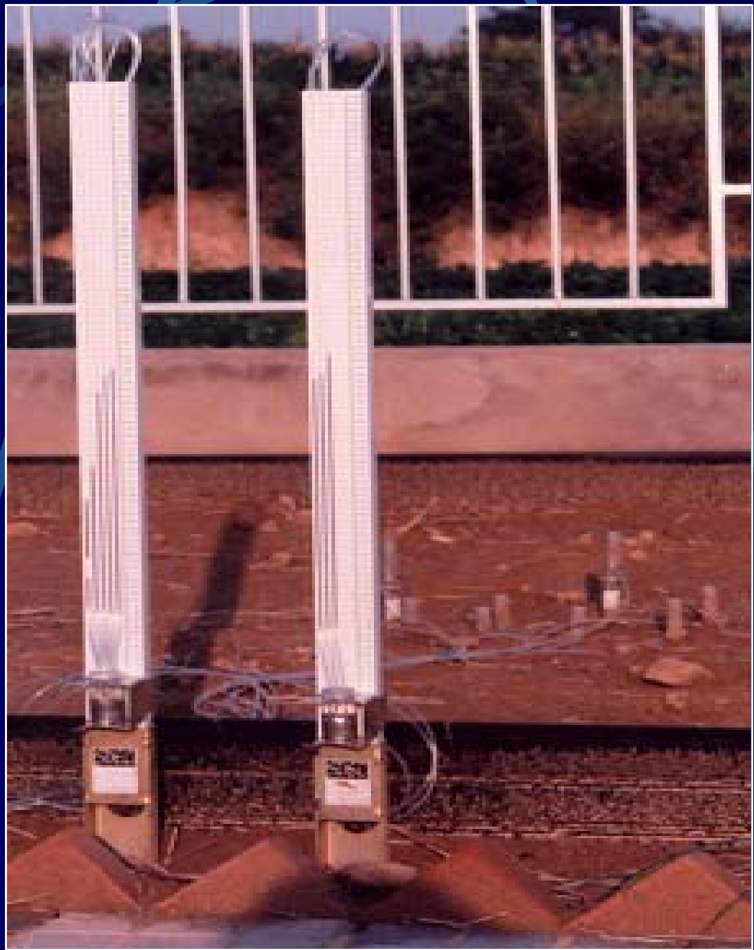
Tipping-bucket rain gauge

Datalogger

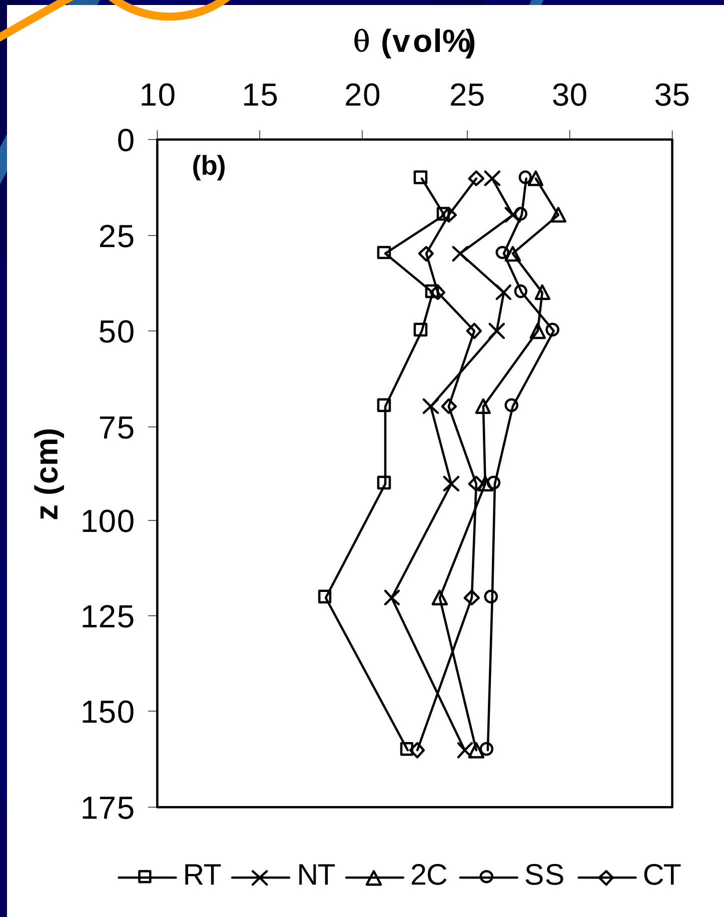
Flume + discharge gauge + drums

Water balance equation

$$\Delta S = P + I - ET - R - D + L_i - L_o$$



Tensiometer sets



day to day readings

The effect of tillage on the soil moisture balance: a case study on the loess plateau of China

Percolation rate (laboratory) and infiltration capacity (field)

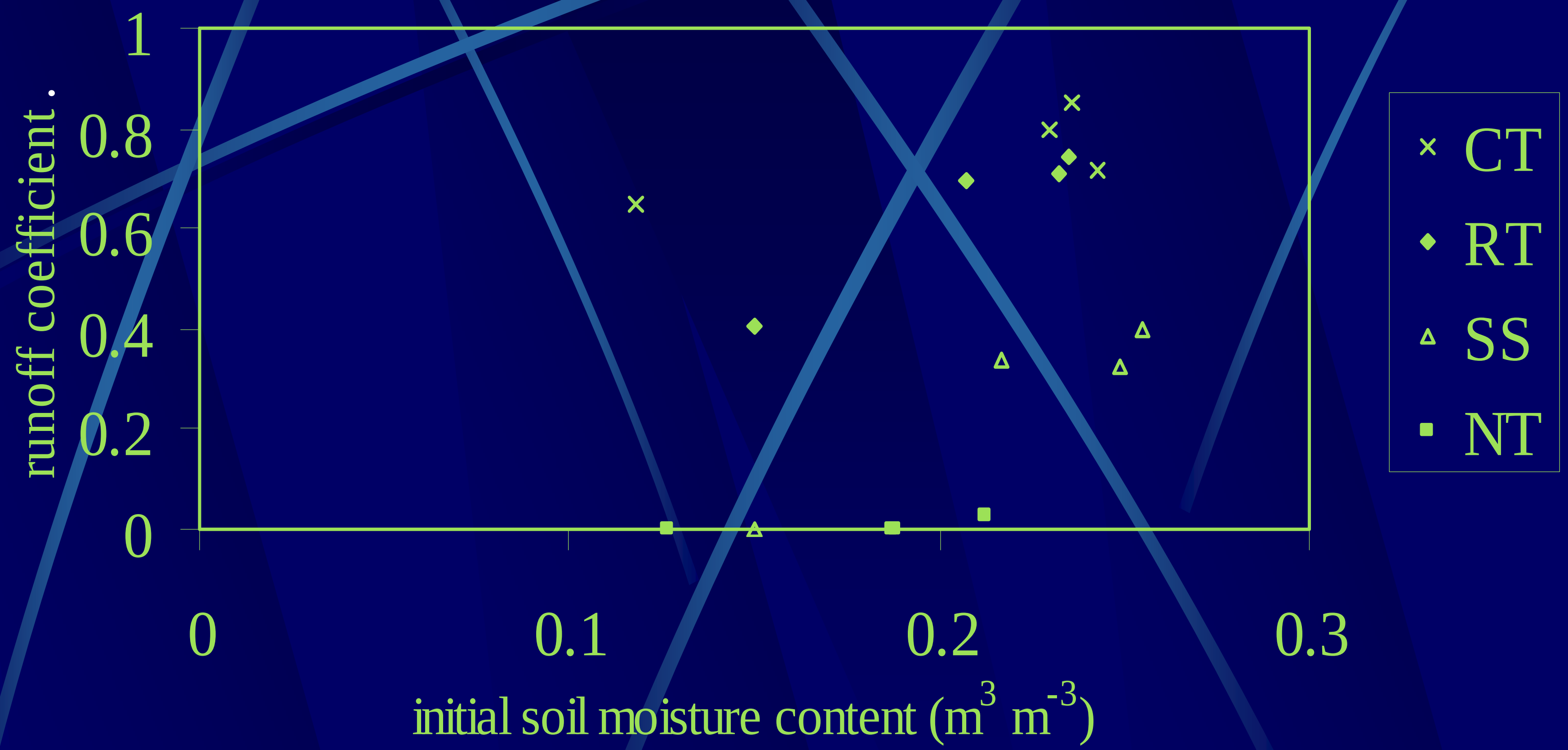
- laboratory

Cover (%)	Percolation ($mm.h^{-1}$)
0	2.9
50	5.5

- field

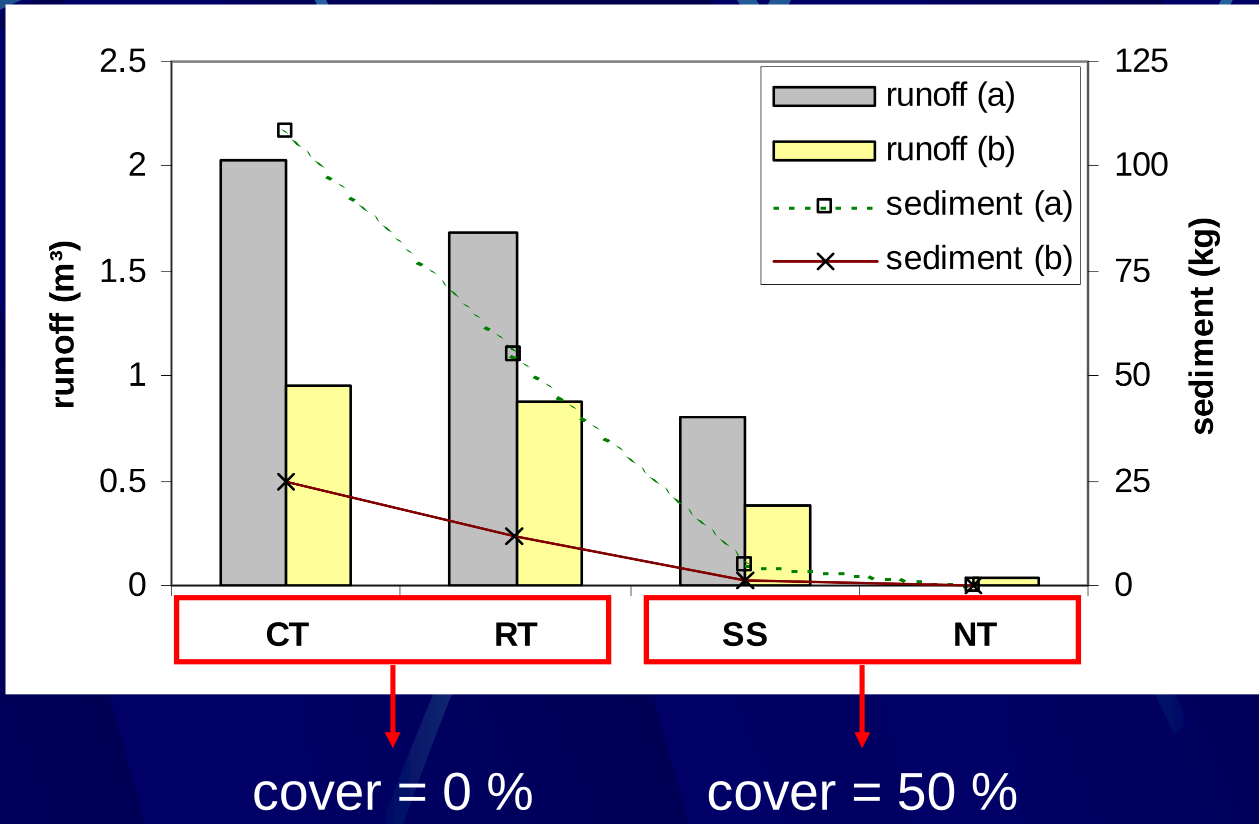
Tillage	Infiltration capacity ($mm.h^{-1}$)
CT	10
RT	18
SS	52
NT	85

→ Tillage practices not only influence runoff through soil cover, but differences in hydraulic conductivity also exist



- Large differences in Runoff Coefficient between different tillage practices are observed
- Even for practices where the straw soil cover is the same (SS and NT)

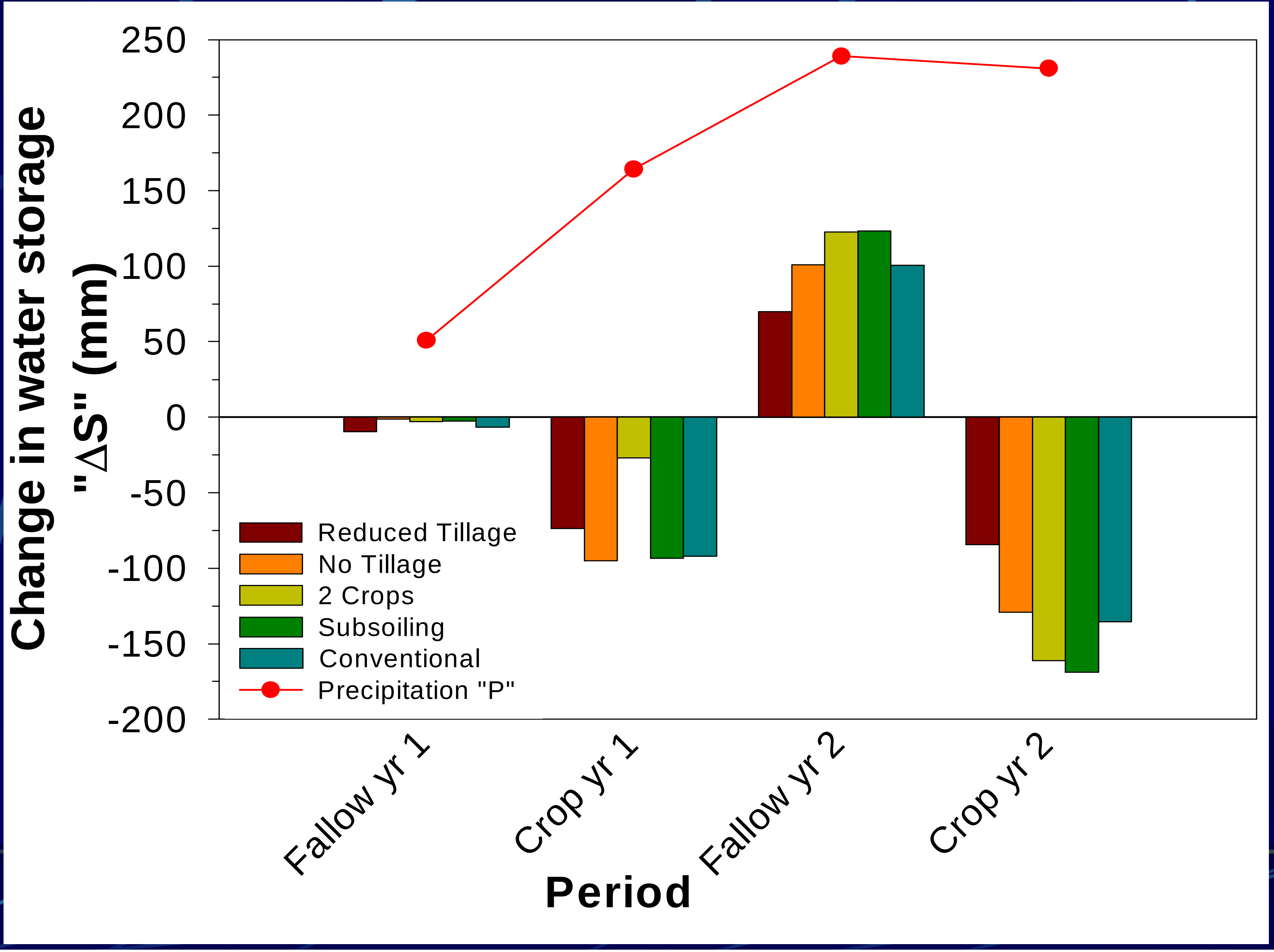
→ runoff and soil loss at rainfall intensities of 176 mm h^{-1} (a) and 88 mm h^{-1} (b)



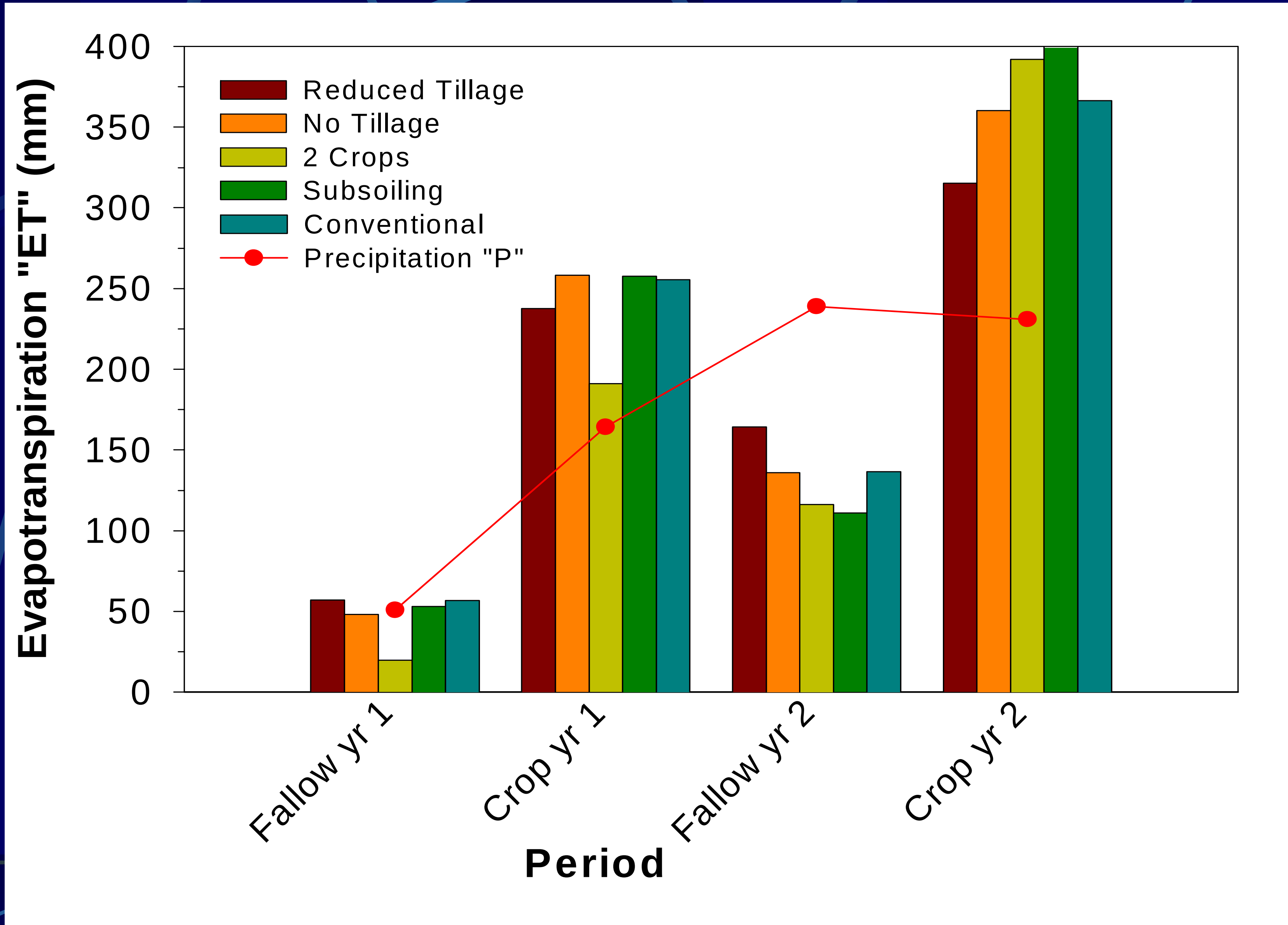
→ Large differences in soil loss between different tillage practices are observed

→ Even for practices with the same straw soil cover (SS and NT)

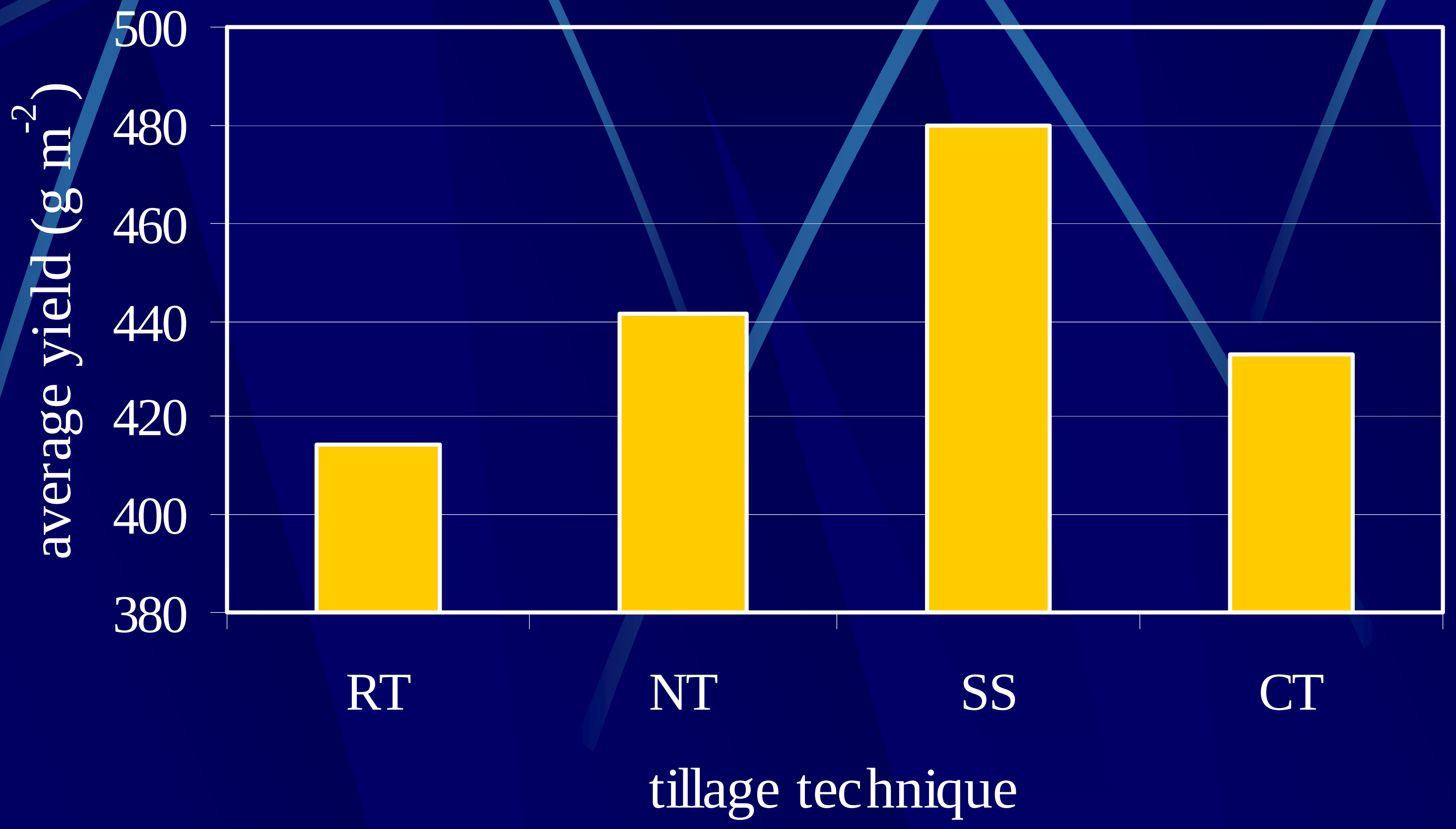
Change in soil water storage ΔS measured with a Trime probe



Calculated evapotranspiration



→ Average annual yield of winter wheat on the field plots (period 1999 – 2003)



Preliminary conclusions (rainfall simulations)

- Large differences in Runoff Coefficient between different tillage practices are observed.
  Even for practices where the straw soil cover is the same (SS and NT)

- Large differences in soil loss between different tillage practices are observed.
  Even for practices with the same straw soil cover (SS and NT)

- Reduction of soil loss by tillage practices results in similar reductions of sediment-bound nutrients

Preliminary conclusions (water balance studies)

- Drainage and runoff are very limited
- Subsoiling is the best practice in terms of water conservation
  - → Highest increase in water storage during the fallow period
  - → Highest evapotranspiration during crop season
- Two crops system shows relatively low ET value in fallow period
  - → High water storage at the start of the winter wheat season
- No-tillage and conventional tillage gave intermediate results
  - → Reduced tillage gave the worst results in terms of water storage

⇒ Further monitoring is necessary to confirm these results

The effect of tillage on the soil moisture balance: a case study on the loess plateau of China

Subsoiler

Applying subsoiling on the field

Part 4: Runoff in small watersheds of Cape Verde


Reforestation in Cabo Verde to combat
human-induced desertification

Quantifying the amount of runoff under different land use systems

Experimental design: 3 catchments with different land uses

W1: afforestation with *Prosopis juliflora* and *Parkinsonia aculeata*
(27.5 ha) absorption bench terraces and microcatchments

W2: natural vegetation (unchanged)
(26.7 ha)

W3: traditional rainfed agriculture, mixed cropping of maize / beans
(15.9 ha)

Untreated catchment on Cape Verde Islands

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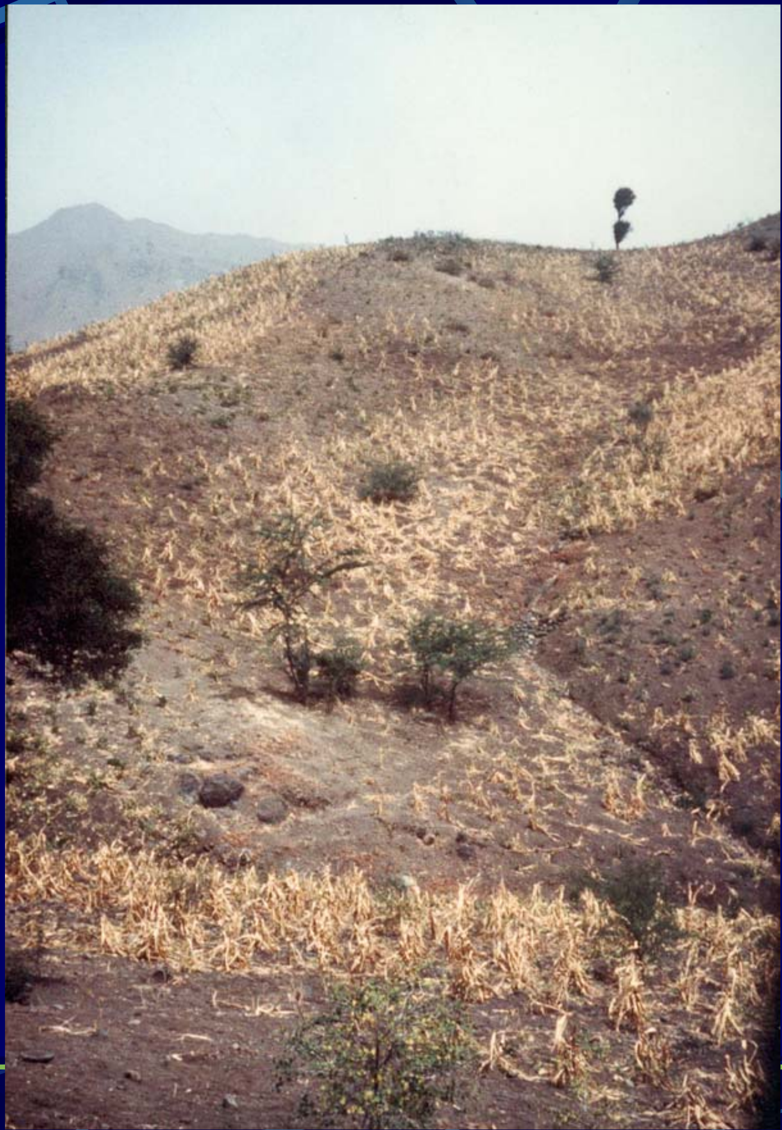
Untreated catchment on Cape Verde Islands



Parshall flume to record catchment streamflow

Runoff in small watersheds of Cape Verde

Parshall flume to record catchment streamflow

Runoff in small watersheds of Cape Verde

Runoff in small watersheds of Cape Verde

Runoff in small watersheds of Cape Verde

- During dry years, W1 (27.5 ha) and W2 (26.7 ha) produce insignificant basin outflow

  → Runoff Coefficient 0.5 - 2%

- During wet years, 15% of annual rainfall is converted into streamflow at basin outlet

- In the traditional land use catchment W3 (15.9 ha) the RC reached 10% in dry years

  ↔ > A third of the rainfall left the basin as stormflow in wet years

Runoff in small watersheds of Cape Verde

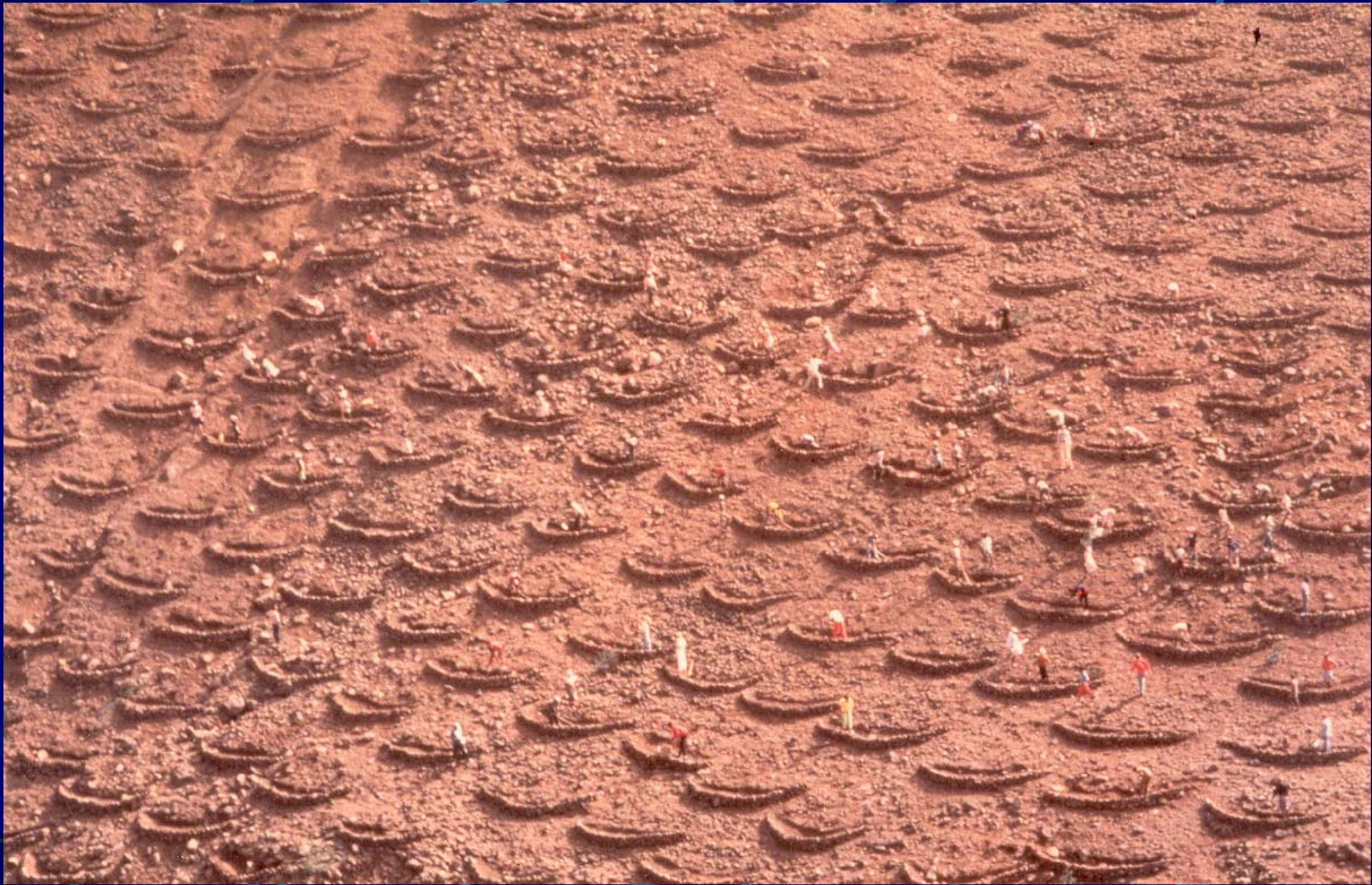
Prosopis juliflora plantation

Water Harvesting Technique in Cape Verde

Water Harvesting Technique in Cape Verde

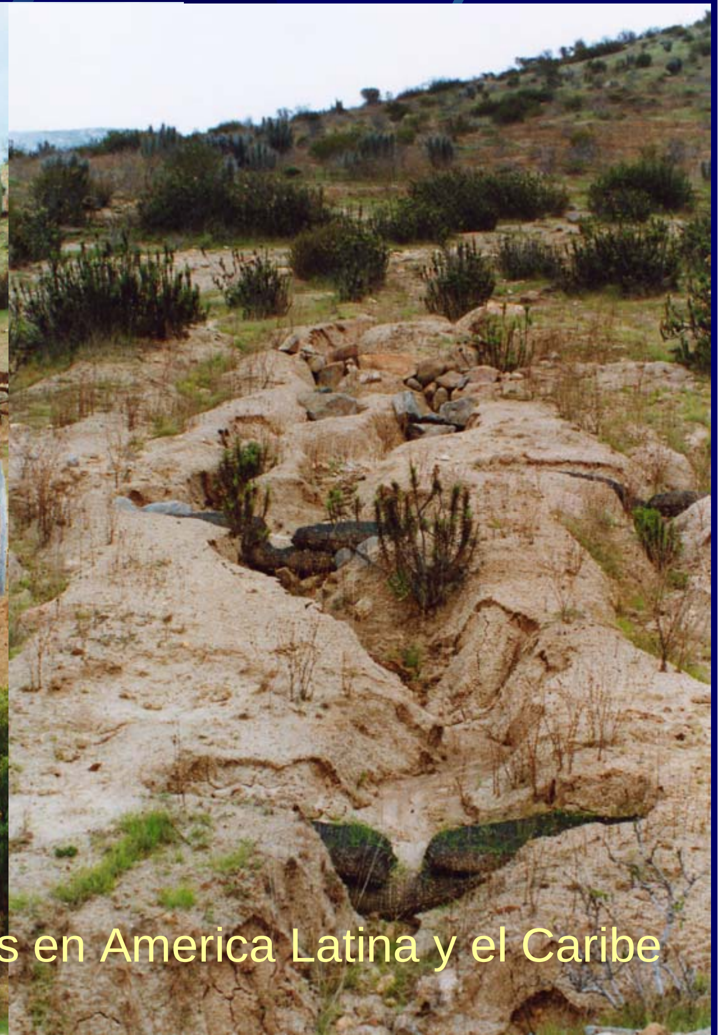
Runoff in small watersheds of Cape Verde

Water Harvesting Technique in Cape Verde



Part 5: Capacity building of Latin-American and Caribbean centre of excellence for arid zone water management (Central Chile)

Capacity building of Latin-American and Caribbean centre of excellence for arid zone water management (Central Chile)



UNESCO fund

with Centro del Agua para Zones Áridas y semi-áridas en America Latina y el Caribe

Study area

Capacity building of Latin-American and Caribbean centre of excellence for arid zone water management (Central Chile)

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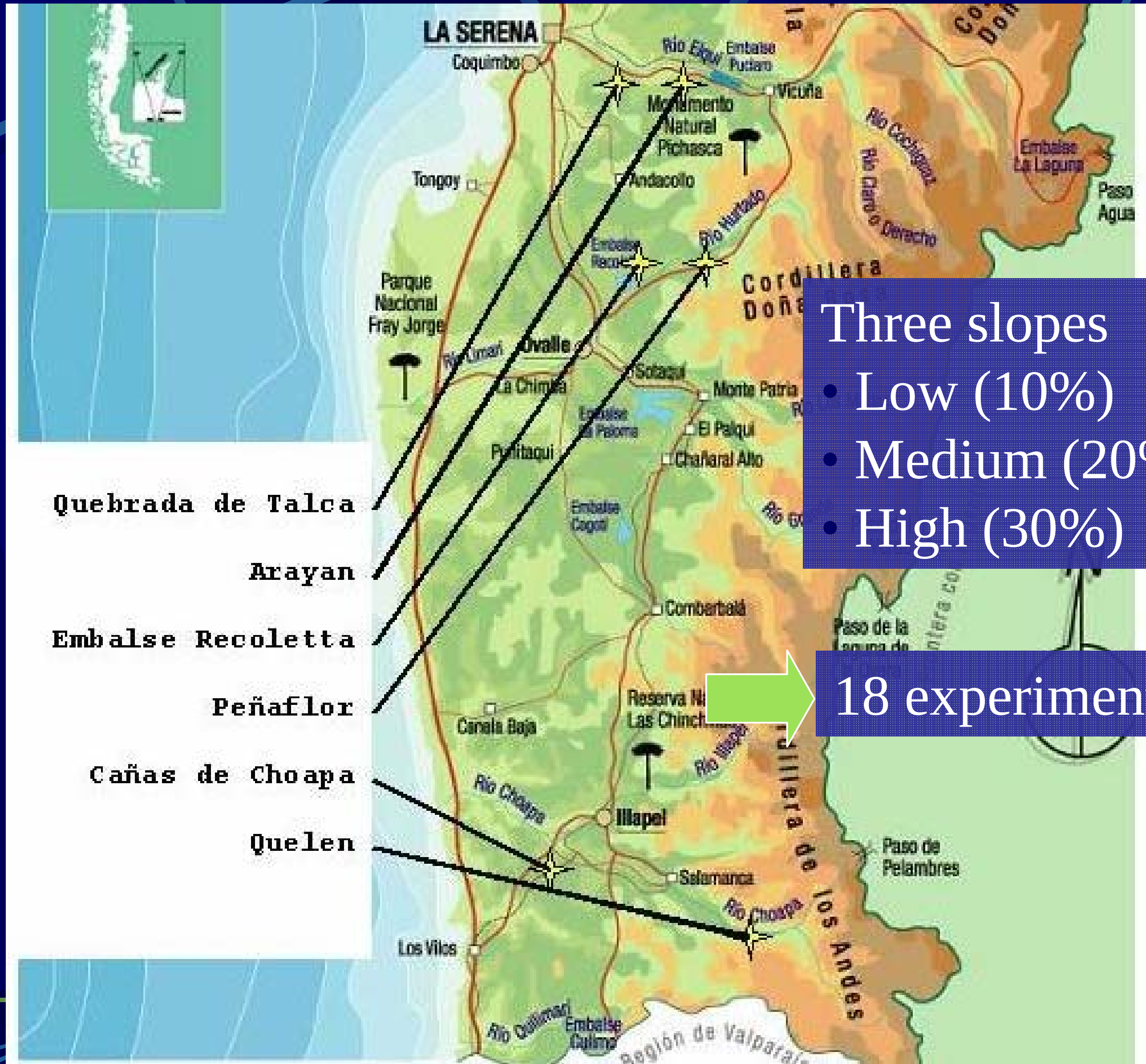
Methodology

Field plots

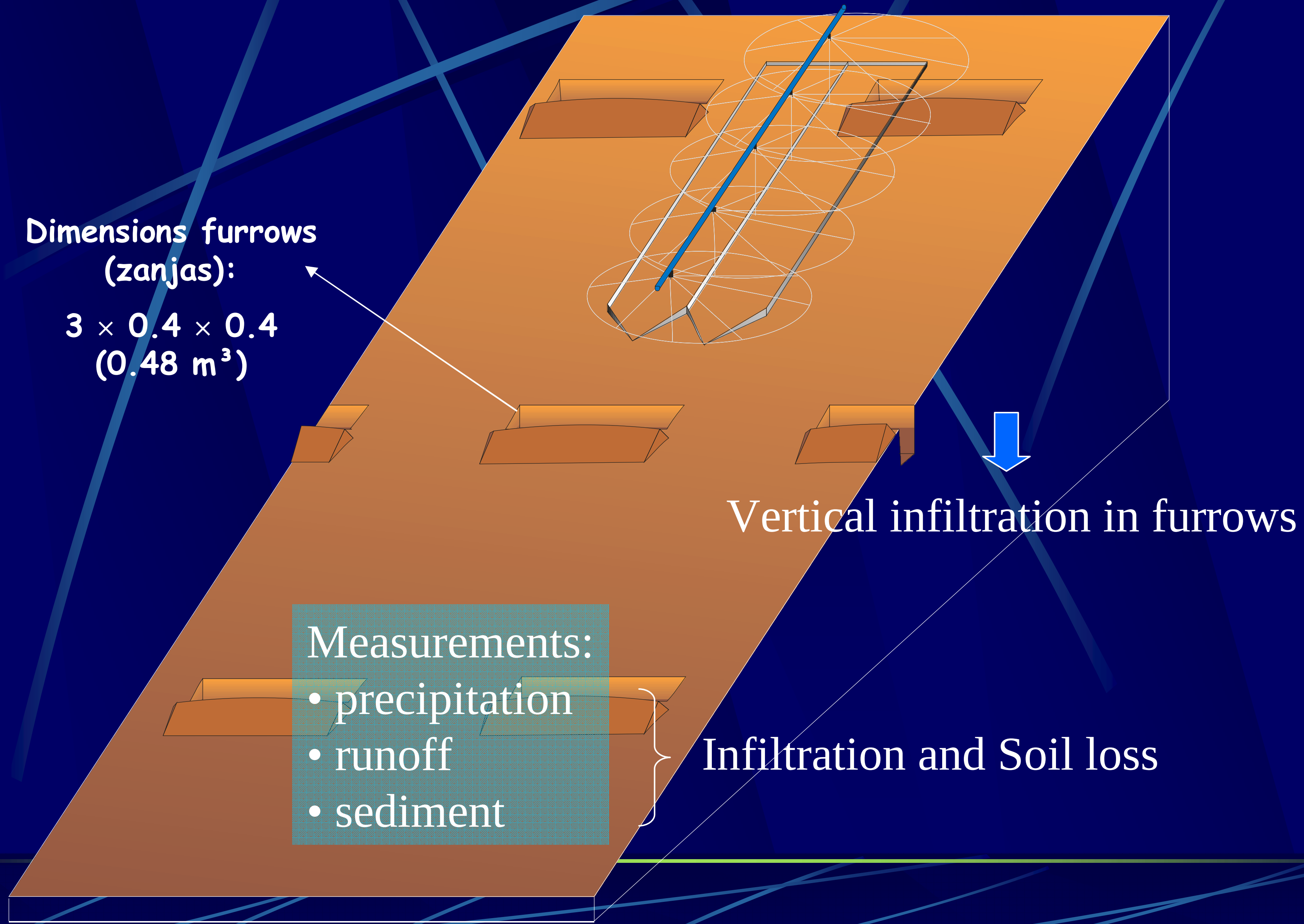


Three slopes

- Low (10%)
- Medium (20%)
- High (30%)

18 experiments

Methodology



Capacity building of Latin-American and Caribbean centre of excellence for arid zone water management (Central Chile)

Results rainfall simulations

Location	P (mm)	I (mm/h)	Runoff (m^3/ ha h)	slope length interval (m)
Quebrada de Talca	44	131	111	15
Arayan	39	117	84	18
Penaflor	36	107	121	12
Embalse Recoletta	34	103	109	15
Cañas de Choapa	39	119	145	12
Quelen	37	110	138	12