Water Resources Engineering and Management

(CIVIL-466, A.Y. 2024-2025)

5 ETCS, Master course

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Platform of hydraulic constructions

Lecture 4-3 Water uses: irrigation for agricultural use

Traditional water uses: irrigation

Scope of irrigation

Artificial supply of water to crops, in addition to natural precipitation; the objective is to create favorable conditions for production, both in terms of quantity and quality

- **Fundamental irrigation**
- **Complementary irrigation**

Main irrigation techniques

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Flood and furrow irrigation

The water is conveyed through a network of canals and distributed over the plots under the effect of gravity forces caused by the slope of the structures and the soil.

Open channel flow hydraulics

Sprinkler irrigation

The water is pressurized and sprayed on the crops in a rain-like manner by means of appropriate equipment.

Pressure flow (turbulent)

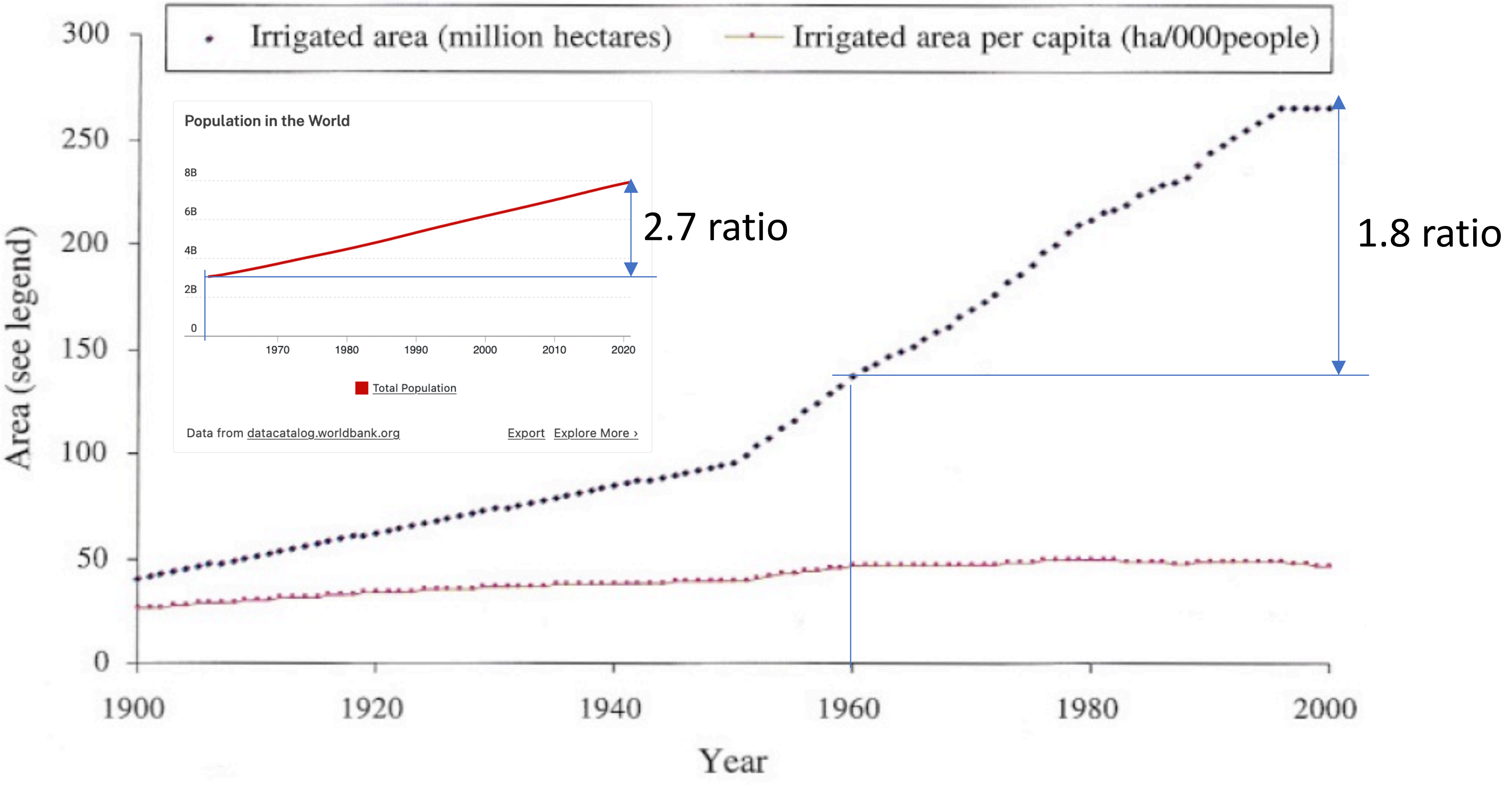
Localized (or drip or micro-) irrigation

L'apport d'eau, à faible débit et à intervalles fréquents, est limité aux zones occupées par les racines des végétaux; le système "goutte à goutte" est le plus utilisé.

Pressure flow (laminar)

Irrigation efficiency

Irrigation is by far the largest source of water use. It has expanded by more than fivefolds in a century (proportional but far less than population increase)



Irrigated area of the world and irrigated area per capita 1900–2000.

However, the increase per capita from almost constant is now decreasing

Increased efficiency in the food production agriculture technology (FAO, 2015)

Furrow irrigation

Sprinkler irrigation

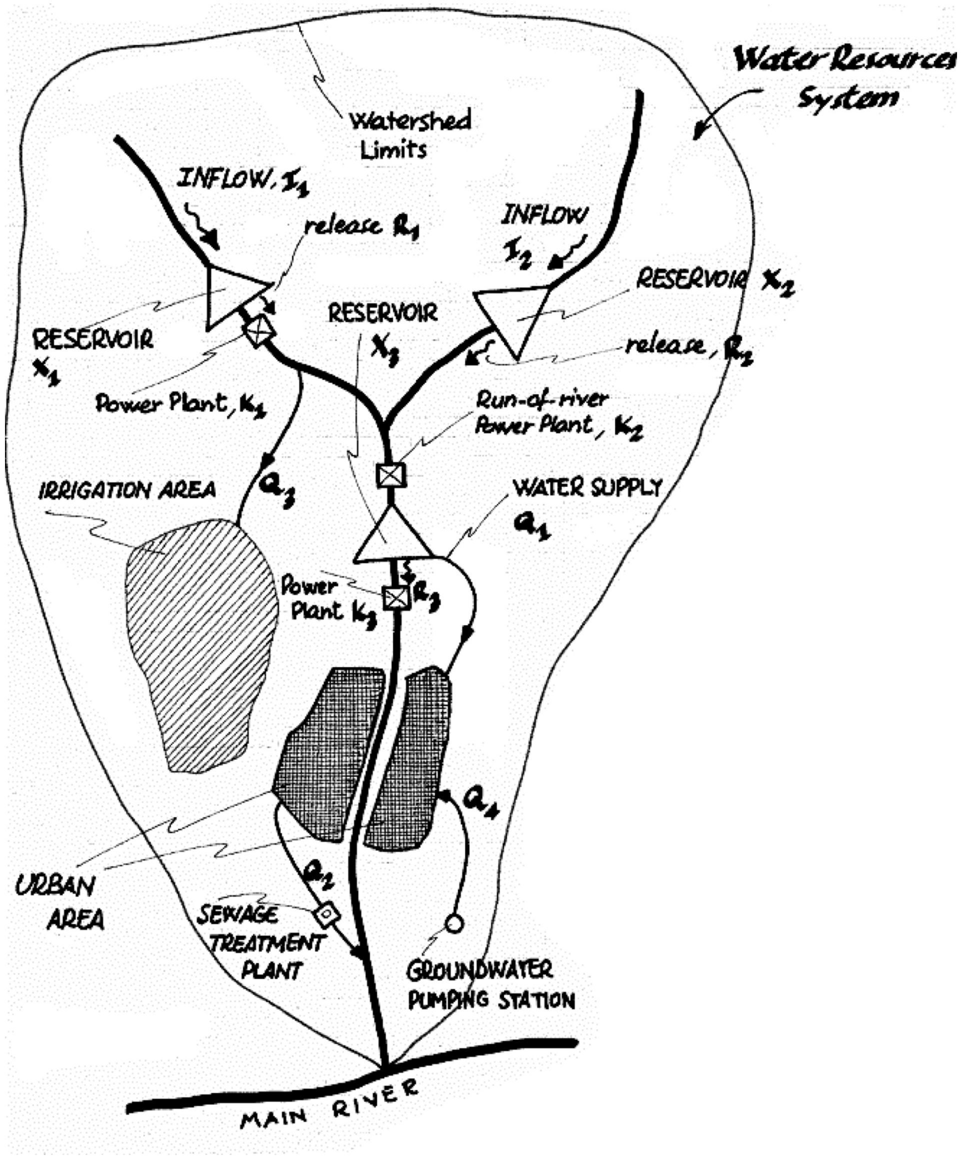
Micro-irrigation

Indicative values of E :

- Gravity Irrigation :
  - Sandy soil 30 – 40 %
  - Silt soil 50 – 60 %
  - Clay Soil 60 – 65 %
- Sprinkler : 65 < E < 85 %
- Micro-irrigation : 85 < E < 95 %

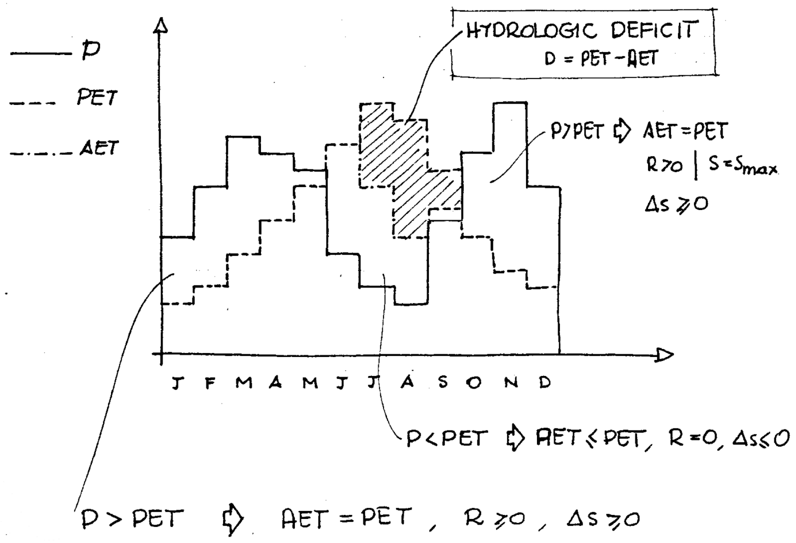
Some typical questions: irrigation needs

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES



What is the amount of water required to satisfy the needs of an irrigated district?

How can we recognize the onset of a drought?



Water needs for agriculture and irrigation amount

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Based on a water balance in the root zone and over a given period (day, decade, month).

The quantity of water naturally available to plants is compared to the water withdrawals of these same plants under optimal water supply conditions (irrigated crop situation).

Available water: - fraction of precipitation stored in the root zone: Pe (effective rainfall)

- possible reserve R*

Withdrawals : - maximum evapotranspiration ETM

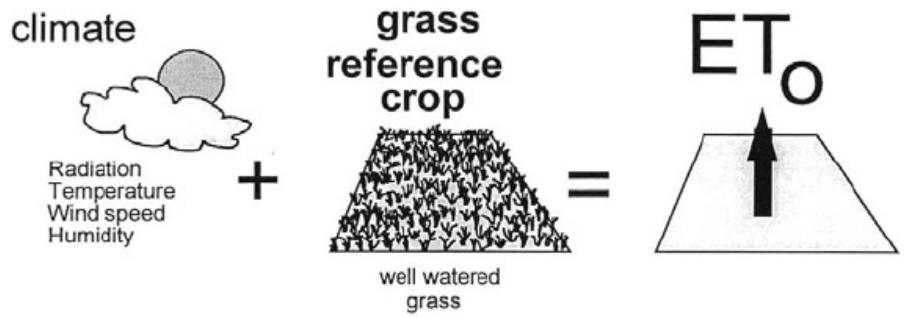
Net request B_n : B_n = ETM - Pe – R = k ET_0 - Pe - R

Max evapotranspiration

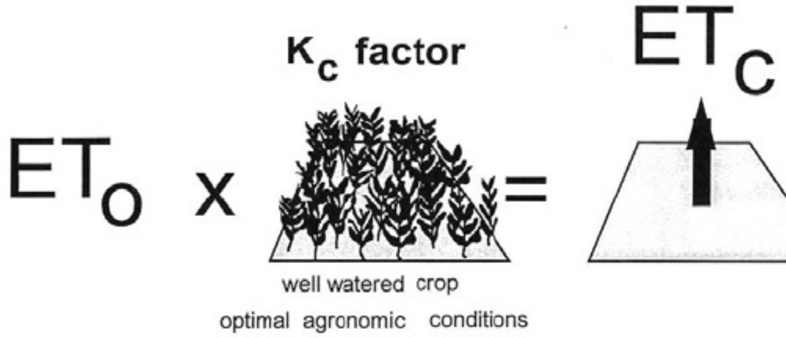
Reference evapotranspiration (Grass in reference conditions)

*** Possible water reserve available in the soil at the beginning of the period for which the water requirements are calculated**

FAO Method

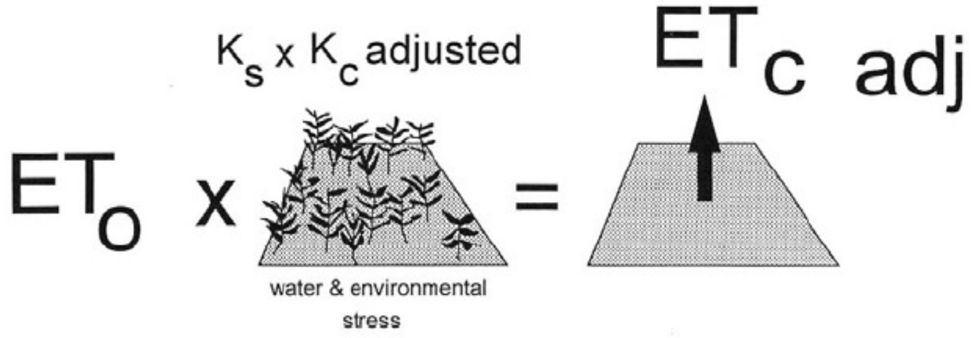


Reference conditions



(ETM)

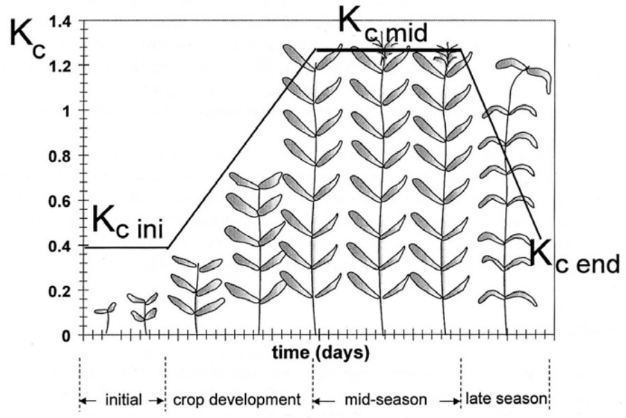
Standard conditions



Non-standard conditions

Crop coefficient K_c

Cultures	Amplitude totale	Période de pointe
Céréales(blé, avoine, orge, maïs, mil, sorgho)	0.2 - 1.2	1.05 - 1.2
Luzerne, trèfle, fourrage	0.3 - 1.25	1.05 - 1.25
Riz	0.95 - 1.35	1.05 - 1.35
Coton	0.2 - 1.25	1.05 - 1.25
Betteraves à sucre	0.2 - 1.2	1.05 - 1.2
Carottes, céleris, pommes de terre	0.2 - 1.15	1.0 - 1.15
Melons, épinards	0.2 - 1.05	0.55 - 1.05
Oignons, crucifères	0.2 - 1.1	0.95 - 1.1
Tomates	0.2 - 1.25	1.05 - 1.25



Notion of irrigation perimeters

- Dominant perimeter P_{dom}
- Irrigated perimeter P_{ir}

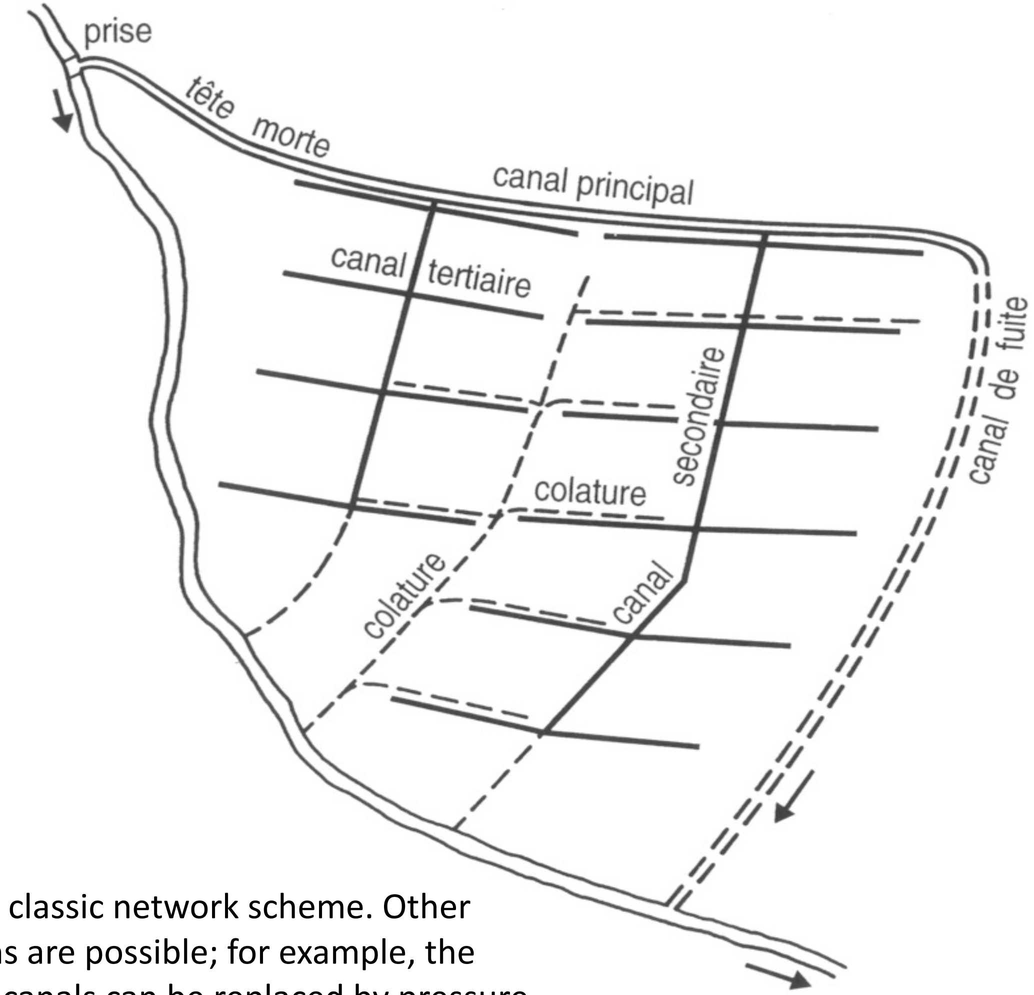
$P_{ir} = \underbrace{P_{dom} - \text{not agric. Zones}}_{P_{gross}} - \text{ways and paths}$

Ways and path zones = 5 à 15 % of P_{gross}

$P_{ir} = P_{gross} - 0.05 \text{ à } 0.15\ P_{gross}$

- Equipped perimeter

General scheme of gravity irrigation network



This is a classic network scheme. Other solutions are possible; for example, the tertiary canals can be replaced by pressure pipes fed by pumps that draw water from the lower-tier canals.

Irrigation water supply

- **Intake structures**
- **Deadhead**
- **Main, secondary, tertiary channels, etc.**

Excess water removal

- **Tertiary, secondary, principal colatures, etc.**

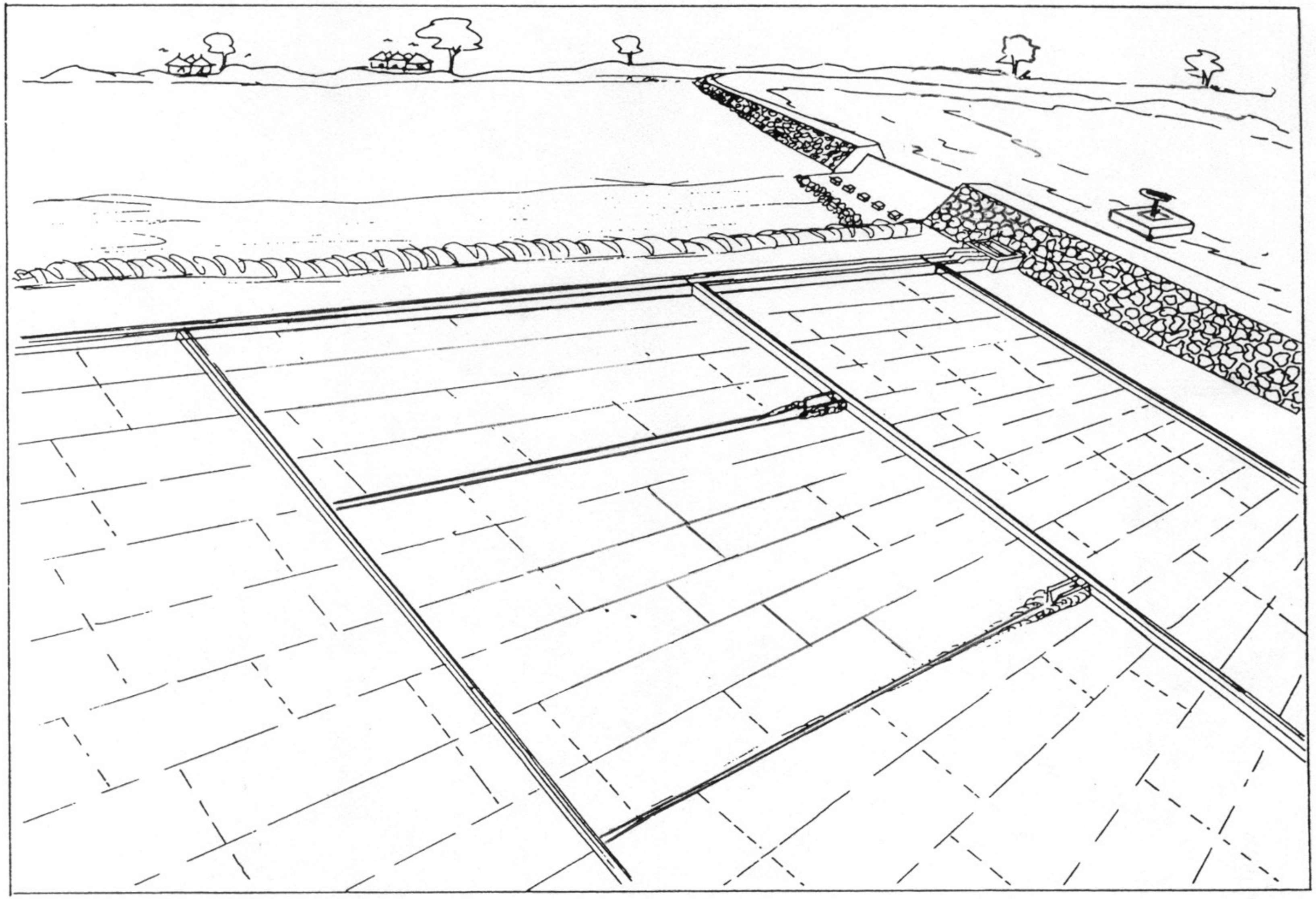
Access to structures and plots

- **Roads and traffic lanes**

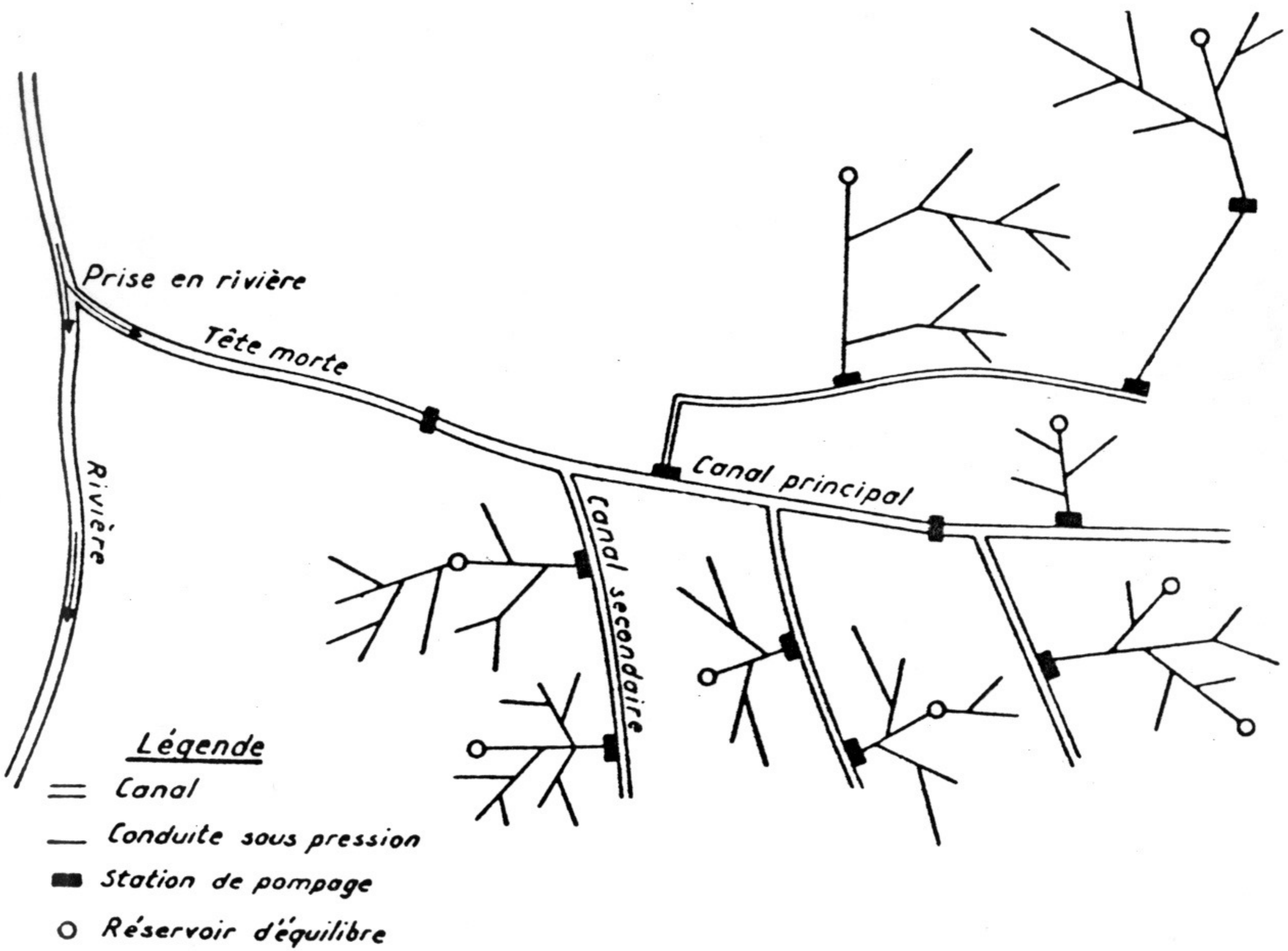
Perimeter security

- **Dykes, drainage ditches, etc.**

Gravity irrigation perimeter fed by artificial reservoir

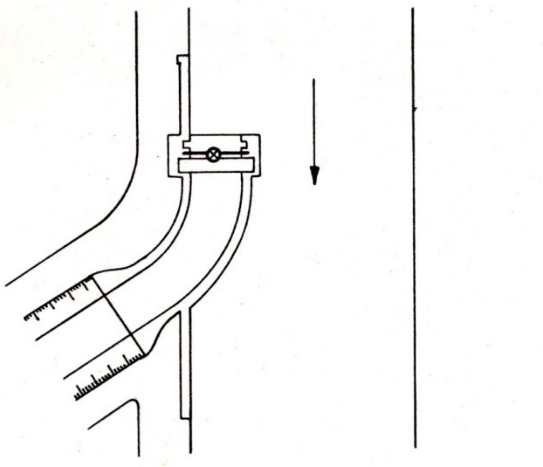


Mixed gravity and pressurized irrigation network

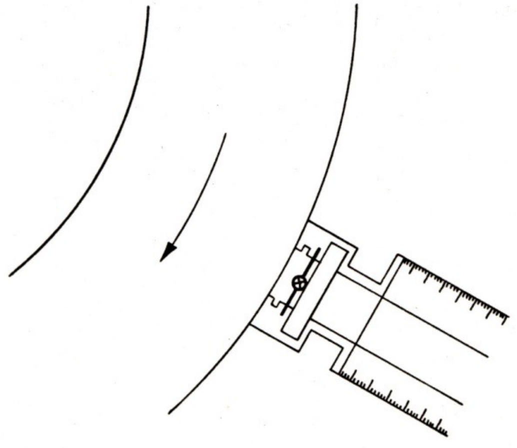


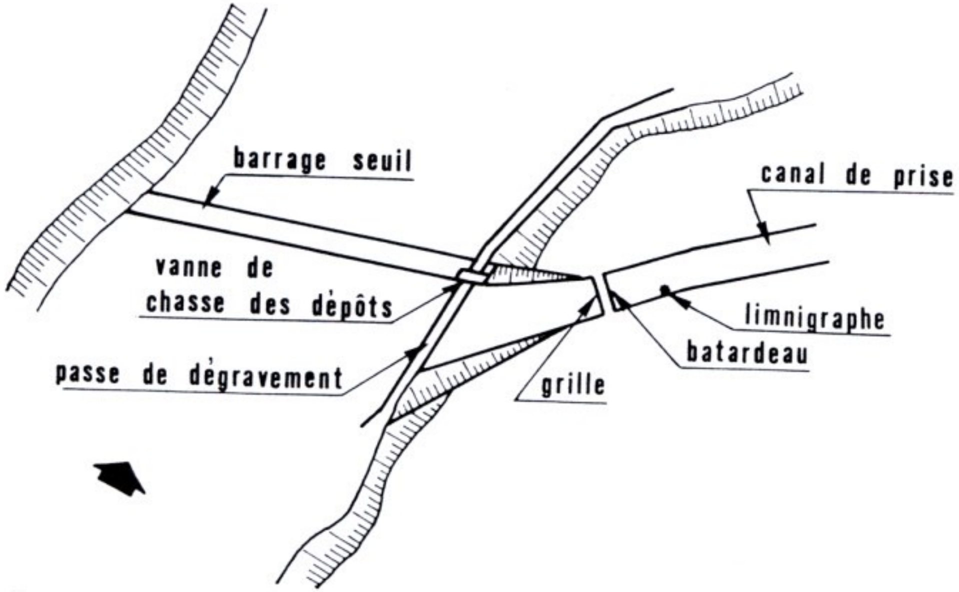
Example of water intakes from water course

PRISE FRONTALE



PRISE LATERALE





Pressurized irrigation schemes

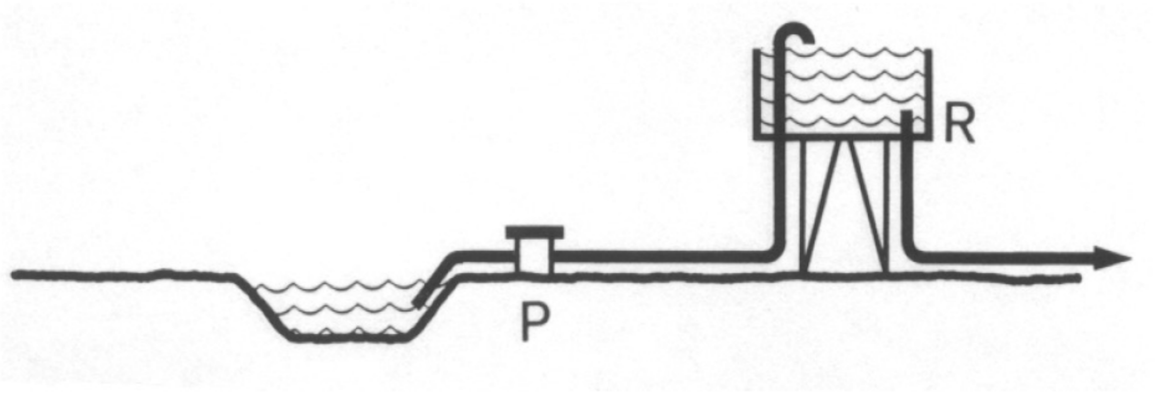


Fig. 1 : Cas du réservoir surélevé

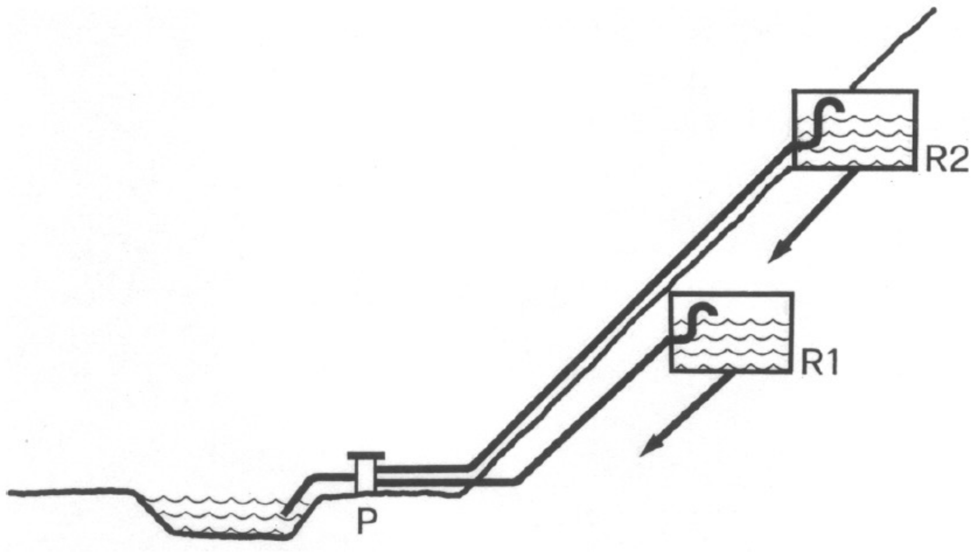


Fig. 3 : Alimentation étagée

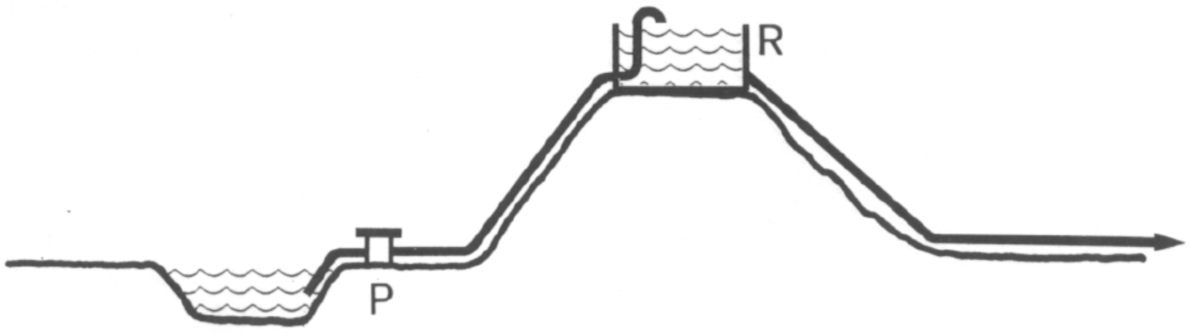
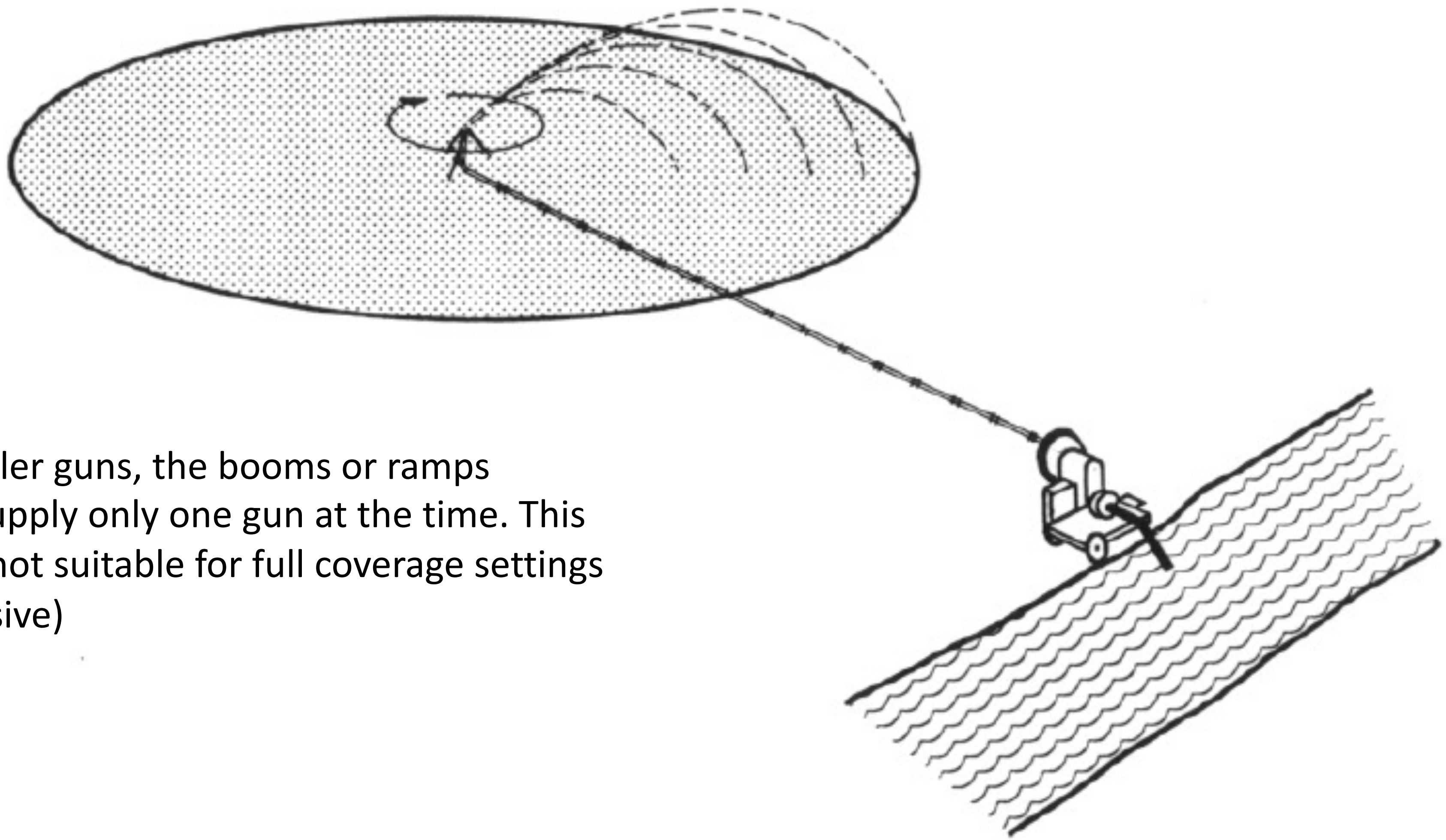


Fig. 2 : Cas du réservoir d'écrêtement

Fig. 4 : Refoulement direct

Mobile installations with sprinkler guns

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES



With sprinkler guns, the booms or ramps generally supply only one gun at the time. This solution is not suitable for full coverage settings (too expensive)

Possible negative impacts of irrigation

Inadequate network design, inappropriate maintenance or poor management can have highly damaging adverse impacts:

1. Alteration of soil properties
2. Lowering the water table
3. Contamination of surface and ground water by fertilisers and pesticides
4. Damage to downstream ecosystems
5. Spread of diseases propagated by vectors associated with water bodies (malaria, schistosomiasis, onchocerciasis)

Localized irrigation or Micro-Irrigation

***Basic characteristics*:**

- localised apportion
- low flow
- at frequent intervals

***Several techniques* :**

- line system (Bas-Rhône system)
- mini-diffuser system
- drip system

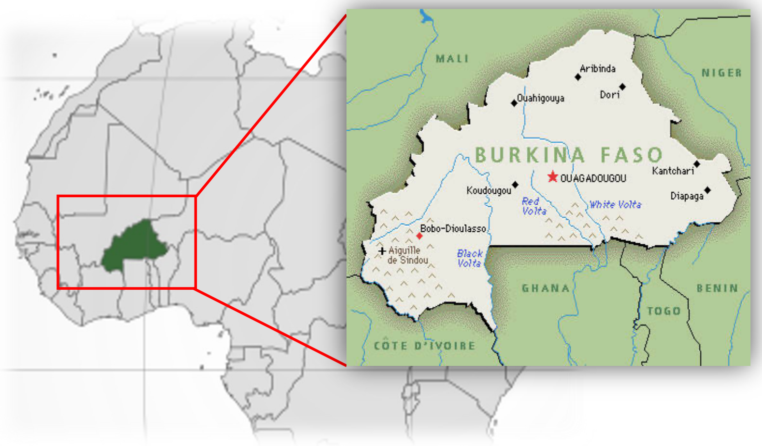
Micro-irrigation has the highest efficiency and the lowest impact on the environment, which explains its rapid development and diffusion across the world

Example: Controlled small-scale irrigation in Burkina Faso

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Burkina Faso | A sub-saharian country with limited natural resources

Location

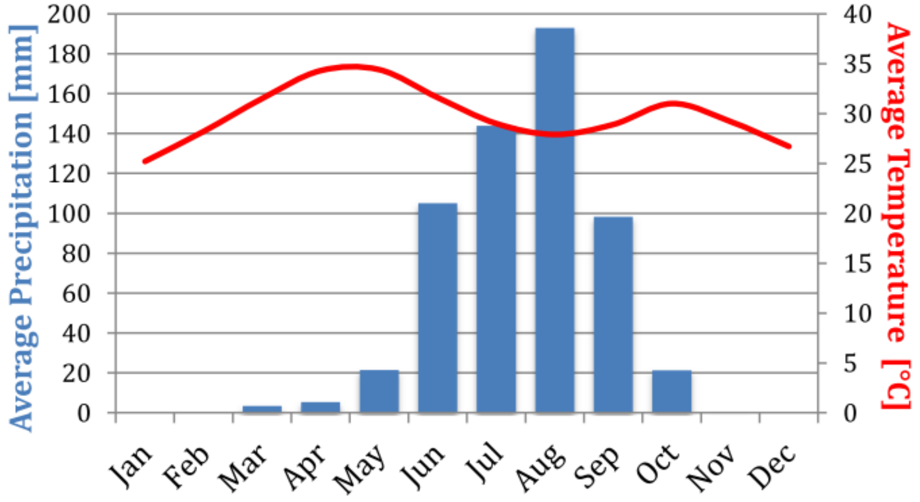


- Rated 181/187 countries regarding human development according to UN
- 46% of pop under the poverty line with 670$/p in 2013 (World Bank)
- Agriculture represents 32% of GDP and occupies 80% of the working population

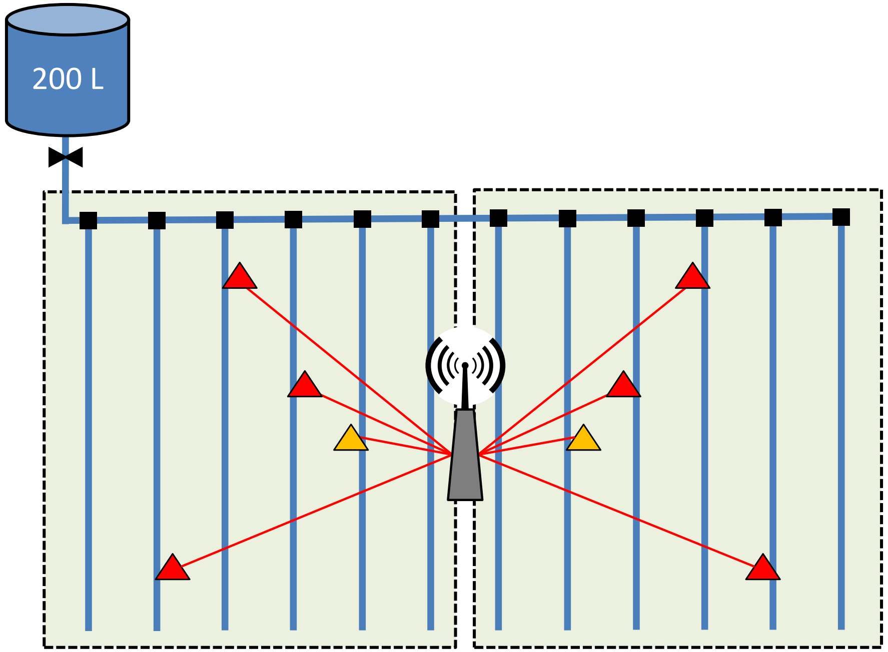
Climate in Burkina Faso

A tropical climate with two very distinct seasons

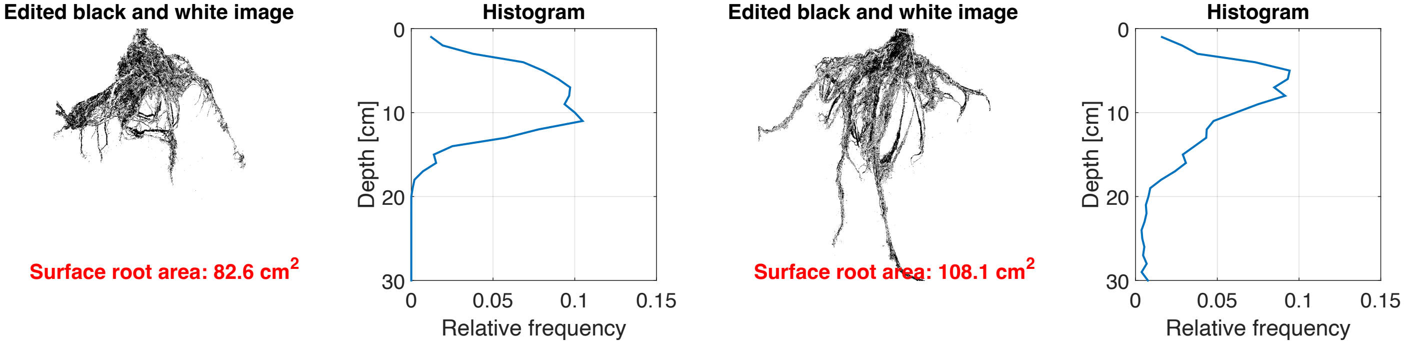
- Rainy season: 4 months of intense rainfall
- Dry season: hot dry wind from the Sahara



Using evolving thresholds for soil moisture helps saving water



IDEA: to perform controlled releases of water (drip irrigation) following feedback from measured soil moisture in the root zone under evolving thresholds (crop species:cabbage)



Müller et al., 2016

Take home messages from these three lectures

- L4.1 I remember (and recognize) different water usesd and their type (consumptive, traditional, etc)
- L4.1 I remember the percentage characterizing water uses across the world
- L4.1 I understand how reservoir design works and can calculate the reservoir size with deterministic inputs
- L4.1 I can explain the concept of reservoir management and best average regulation
- L4.1 I understand and can explain long-term statistical reservoir design based on Hurst effect

- L4.2 I remember population dynamic equations and can explain the principle of the logistic growth model
- L4.2 I know the concept of carrying capacity
- L4.2 I can write the equation terms for the domestic and industrial water demands
- L4.2 I understand and can explain pipeline management cases I, II, III

- L4.3 I know the difference between constitutive and complementary irrigation and the different types
- L4.3 I understand why the irrigation efficiency is different
- L4.3 I can explain the water balance and the FAO method (but don't need to known kc vuales by heart)
- L4.3 I can sketch a general irrigation network perimeter and its main components.
- L4.3 I undestand the basics of micro-irrigation