Irrigation and Drainage Engineering

(Soil Water Regime Management)

(ENV-549, A.Y. 2025-26)

4ETCS, Master option

Prof. Paolo Perona
Platform of Hydraulic Constructions

Lecture 1-1: Introduction, history of irrigation and irrigation methods

General infos

Discipline: Environmental Engineering

Language: English

Session: Winter

Semester: Fall

Exam type: Oral

Workload: 120 h

Weeks: 14

Hours week: 4 h(Tuesday 12:15 – 16:00)

Course: 2 h

Exercises: 2 h (7 weeks)

Project: 2 h (5 weeks, including presentation, TBD)

Instructors

Course Organizer and Instructor
Prof. Dr. Paolo Perona

paolo.perona@epfl.ch

Office: GC A3 515
Tel. 021-6935710

Assistant (Class exercises)
Yahel Eliyahu-Yakir

yahel.eliyahu-yakir@epfl.ch

Office: GC A3 474
Tel. 021-6936532

Assistant (Course project)
Dr. Giulio Calvani

giulio.calvani@epfl.ch

Office: GC A3 505
Tel. 021-6932838

Summary and learning map

This course is a prime about

Soil Water Regime Management

The course aims at teaching the fundamentals of both irrigation and drainage techniques with particular attention to the soil water balance and related management, the materials, the construction methods as well as the environmental impacts and sustainability criteria of both practices.

Irrigation

Drainage

L1. Introduction, history of irrigation, roots and soil

L2. Plant water needs and network design

L3. Open channel flow hydraulics (Review). Canals design

L4-5. Gravity irrigation and control infrastructure

L6-7. Sprinkler and micro irrigation

L8-9. Impacts of irrigation and drainage

L10--11. Drainage principles and techniques

L12-13. Drainage materials, practice and impact

L14. WRAP-UP and exam questions

Irrigation and drainage engineering

PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

1st Part: Irrigation concepts, methods and techniques

Academic Calender 2025-26 Irrigation and Drainage Engineering (ENV-549)					
	Date	Time	Lecture topic	Delivery date	Who
1	09.09.25	12:15 - 13:00	IDE-L1-1 - Introduction, history and methods		PP
		13:15 - 14:00	IDE-L1-2 - Overview of plant roots		
		14:15 - 15:00	IDE-L1-3 - Elements of soil physics and water quality		
		15:15 - 16:00	Presentation Exercises and Project		
2	16.09.25	12:15 - 13:00	IDE-L2-1 - Determination of plant water needs		PP
		13:15 - 14:00	IDE-L2.2 - Irrigation network conceptual design		
		14:15 - 15:00	IDE-Exercise 1: rainfall analysis & water needs (1 ex)		
		15:15 - 16:00		22.09.25	YY
3	23.09.25	12:15 - 13:00	IDE-L3.1 - Gravity irrigation: hydraulic review + canals		GC
		13:15 - 14:00	IDE-L3.2 - Gravity irrigation: conveyance and design		
		14:15 - 15:00	IDE-Exercise 2: gravity irrigation basic study + canal (2 exs)	29.09.25	YY
		15:15 - 16:00			
4	30.09.25	12:15 - 13:00	IDE-L4.1 - Gravity - embankments and lining		GC
		13:15 - 14:00	IDE-L4.2 - Gravity - upstream control and regulation		
		14:15 - 15:00	IDE - Exercise 3: gravity irrigation: sizing weirs and canals (2 exs)	06.10.25	YY
		15:15 - 16:00			
5	07.10.25	12:15 - 13:00	IDE-L5.1 - Gravity - distribution plus security		PP
		13:15 - 14:00	IDE-L5.2. Gravity (plot redistribution) - plus visit to the flume campus		
		14:15 - 15:00	IDE - Exercise 4 - Gravity irrigation: infrastructures design, bottom opening + inverse siphon (2 exs)	13.10.25	YY
		15:15 - 16:00			
6	14.10.25	12:15 - 13:00	IDE-L6.1 - Sprinkler: basic principles		PP
		13:15 - 14:00	IDE-L6.2 - Sprinkler: hydraulic design and pumping		
		14:15 - 15:00	IDE - Exercise 5 - Sprinkler: aqueduct + sprinkler system (2 exs)	28.10.24	YY
		15:15 - 16:00			
7	28.10.25	12:15 - 13:00	IDE-L7.1 - Sprinkler: techniques and frost fighting		PP
		13:15 - 14:00	IDE-L7.2 - Micro irrigation 1		
		14:15 - 15:00	IDE - Exercise 6 - Curved pipe anchorage +microirrigation (2 exs)	04.11.24	YY
		15:15 - 16:00			
8	04.11.25	12:15 - 13:00	IDE-L8.1 - Micro and subsoil irrigation		PP
		13:15 - 14:00	IDE-L8.2 - impact of irrigation 1		
		14:15 - 15:00	Free to wrap up		YY
		15:15 - 16:00			

2nd Part: Drainage of Agricultural soils

8	04.11.25	12:15 - 13:00	IDE-L8.1 - Micro and subsoil irrigation		PP
		13:15 - 14:00	IDE-L8.2 - impact of irrigation 1		
		14:15 - 15:00	Free to wrap up		YY
		15:15 - 16:00			
9	11.11.25	12:15 - 13:00	IDE-L9.1 - Impact of Irrigation 2		PP
		13:15 - 14:00	IDE-L9.2 - Drainage 1		
		14:15 - 15:00	Course Project 1	09.12.24	GC
		15:15 - 16:00			
10	18.11.25	12:15 - 13:00	IDE-L10.1 - Drainage 2	09.12.24	PP
		13:15 - 14:00	IDE-L10.2 - Drainage 3		
		14:15 - 15:00	Course Project 2		GC
		15:15 - 16:00			
11	25.11.25	12:15 - 13:00	Course Project 3	09.12.24	GC
		13:15 - 14:00			
		14:15 - 15:00	IDE-L11.1 - Drainage 4		PP
		15:15 - 16:00	Guest lecture		ER
12	02.12.25	12:15 - 13:00	IDE-L12.1 - Drainage 5		PP
		13:15 - 14:00	IDE-L12.2 - Drainage: materials		
		14:15 - 15:00	Course Project 4	09.12.24	GC
		15:15 - 16:00			
13	09.12.25	12:15 - 13:00	IDE-L13.1 - Drainage: impact		PP
		13:15 - 14:00	IDE-L13.2 - Regenerative agriculture		
		14:15 - 15:00	IDE - Exercise 7 Drainage Haute-Broye and draining trench (2 exs)	16.12.24	YY
		15:15 - 16:00			
14	16.12.25	12:15 - 13:00	IDE-L14 - Conclusive Guest lecture		VN
		13:15 - 14:00	IDE-L14 - Wrap up and oral exam questions discussion		PP
		14:15 - 15:00	Project presentations (TBD) and closure		PP,GC,YY
		15:15 - 16:00			

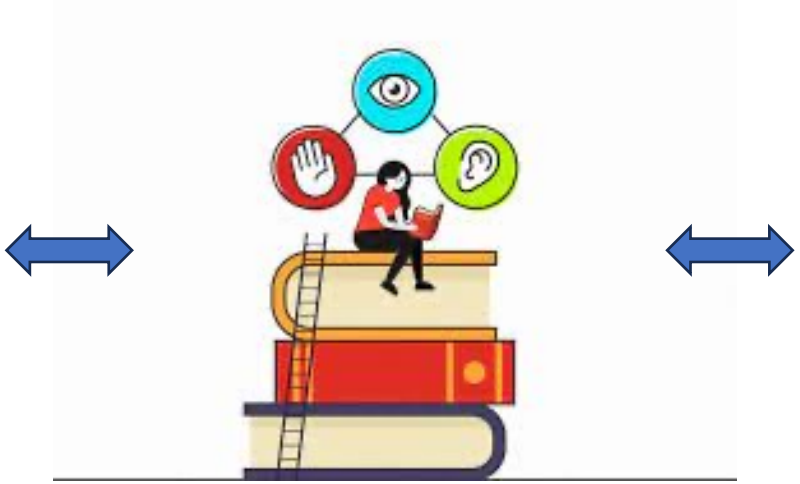
Learning objectives and transversal skills

LEARNING OBJECTIVES

- Judge the problematics following water both scarcity and excess
- Elaborate adequate solutions
- Sketch both irrigation and drainage setups
- Model basic physical aspects of irrigation and drainage schemes

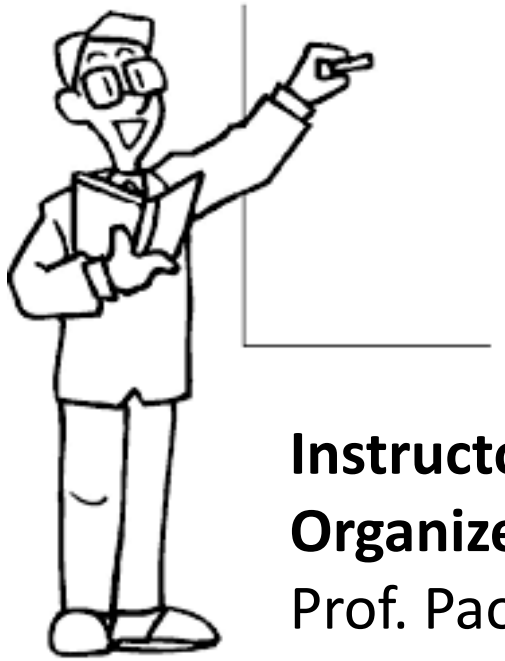
TRANSVERSAL SKILLS

- Set objectives and design an action plan to reach those objectives.
- Use a work methodology appropriate to the task.
- Take feedback (critique) and respond in an appropriate manner.



Teaching method and student activities

Lectures: Ex cathedra, with audiovisual means and board complementary explanations/derivations



Instructor and Course Organizer
Prof. Paolo Perona

Exercises: 7 Assignements (2 exs/each) work in class/home (free) delivery dates 1 week after ex.

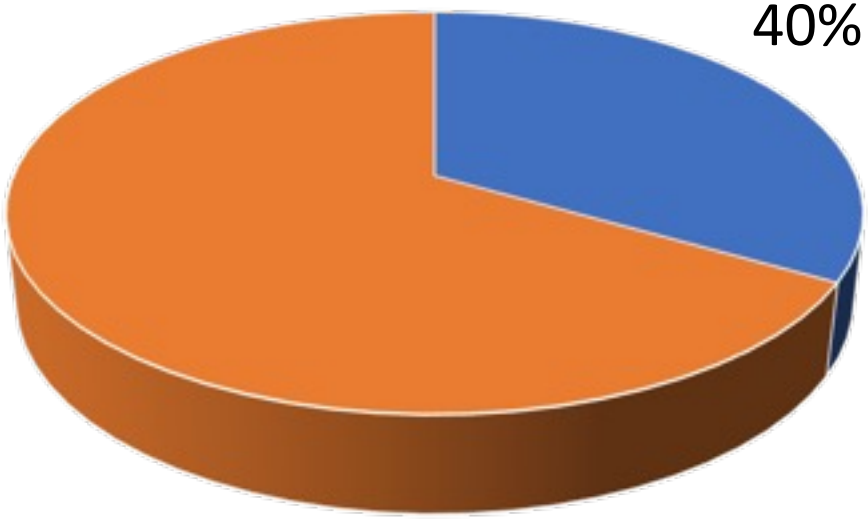
Responsible: Yahel Eliyahu-Yakir

Project: Conceptual development of irrigation and drainage solution in the ambit of the EIRA project

Responsible: Dr Giulio Calvani

Assessment methods

40% Homework (Exercise 20%; Project 20%)

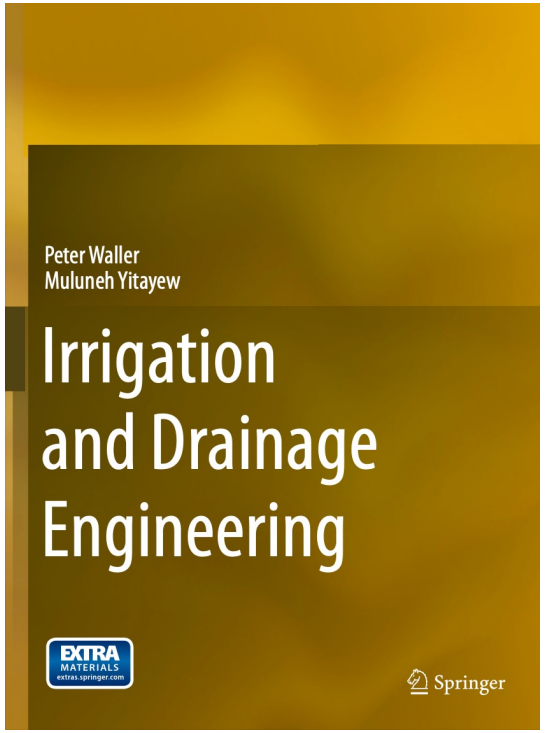


60% Oral exam

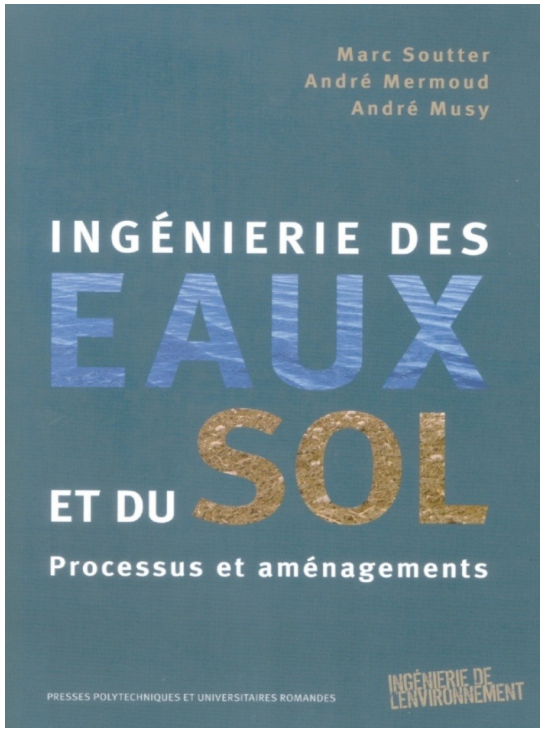
- Exercises and project are compulsory in order to access the final exam
- The exam is only oral, but with handwritten answers to the Instructor‘s questions
- In general, 3 questions, sampled by the student randomly from three pots (difficult, medium, easy)
- The exam lasts 30 min. The official language (lectures+exam) is English.

Material

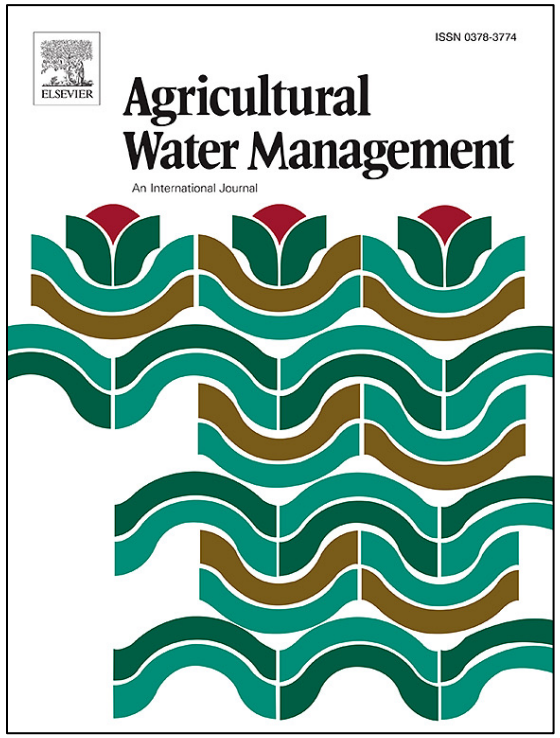
Book



Book



Journal



PLATEFORME DE CONSTRUCTIONS HYDRAULIQUES

Enjoy the course, the semester and…remember…

EPFL has great locations where to relax!

Irrigation and Drainage Engineering (ENV-549)

History of irrigation (from Waller and Ytayew, 2016)

The artificial supply of water to crops to supplement natural rainfall; the aim is to create favorable conditions for production, in terms of both quantity and quality.

Irrigation proceeded together with civilization and strongly feedback on it

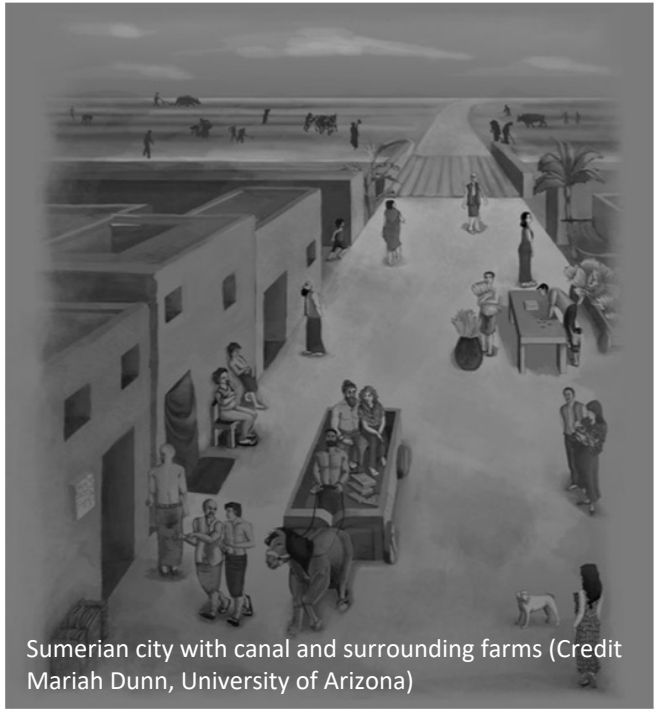
6000 B.C. Ubaid and Sumerians (Ancient Mesopotamia)

Formed civilization and invented intensive irrigation

1% population working in irrigated farms feeds the rest living in large cities

1750 B.C. Hammurabi Babylonian king

"When Anu and Bel (gods) gave me the land of Sumer and Akkad to rule,... I dug out the Hammurabi-canal named Nuhus-nisi. Both the banks thereof I changed to fields for cultivation, and I garnered piles of grain, and I procured unfailing water for the land. As for the land of Sumer and Akkad, I collected the scattered peoples thereof, and I procured food and drink for them. In abundance and plenty I pastured them, and I caused them to dwell in peaceful habitation. "



Sumerian city with canal and surrounding farms (Credit Mariah Dunn, University of Arizona)

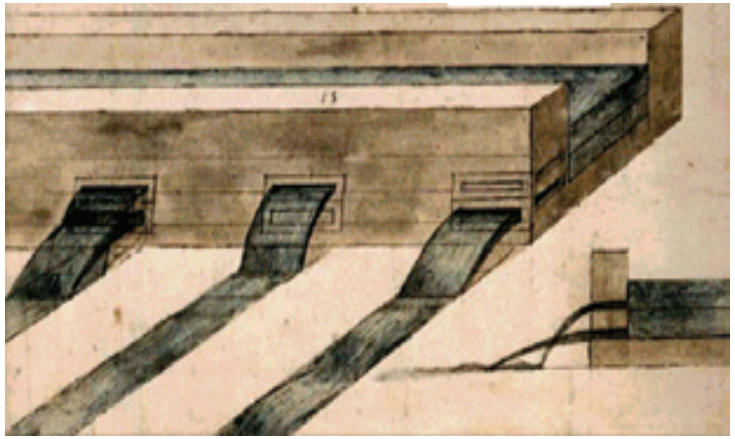
Egyptians learned the practice of intensive agriculture from the Sumerians and the periodic floodings of the Nile River

3300-1300 B.C. Indus Valley Civilization became the largest in the ancient world (up to 5M people). **Prolonged severe drought caused civilization collaps** around 1800 B.C.

Today the Indus River Irrigation system provides water to about 16.2 Mha →largest irrigation system of the world

1600 – 1400 B.C. The native americans Hohokam used water for irrigation purposes and to flourish → **destroyed by an extended drought** around the thirteen century B.C.

250 B.C. Chinese engineer Zheng-Guo used Yellow River waters to irrigate 80000 ha in Qin Province. Today the Dujianyan diversion system irrigates 5300 km^2 (530000 ha)



Il canale di San Cristoforo, Milano Navigli
L. Da Vinci (1509)

The Adda and the Martesana
Between Vaprio and Trezzo. L. DaVinci

The land between the Adda and Brembo

Il territorio tra Adda e Brembo, XVIII sec, Venezia, Archivio di Stato

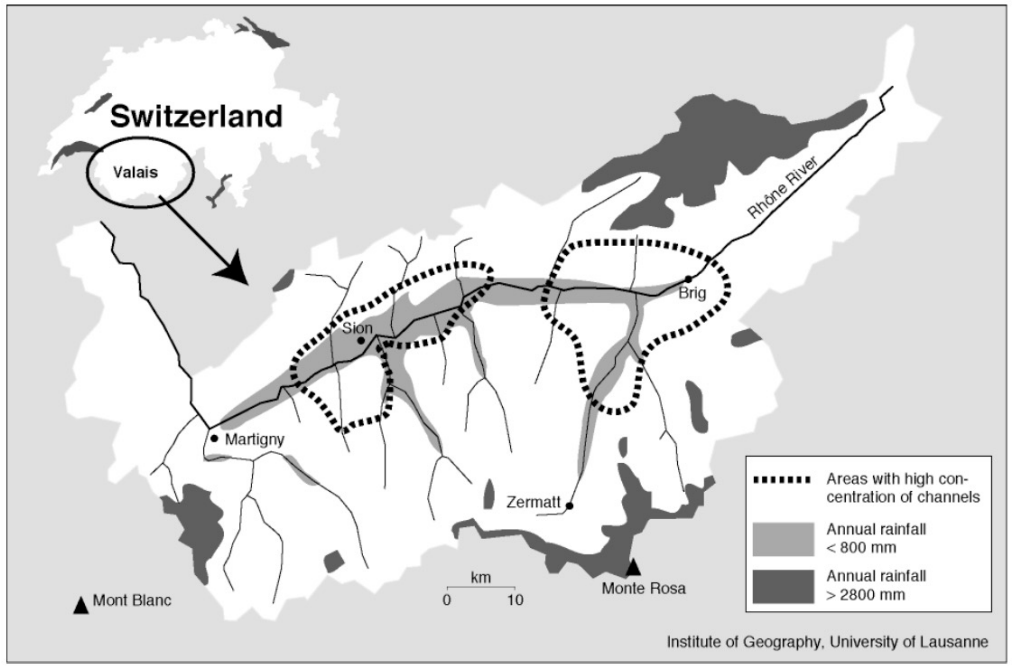
The territory between the Adda and Brembo, 13th century, Venice, Archivio di Stato

…and in Switzerland?

- Long tradition (>750 years in Wallis)

- Rhone Valley

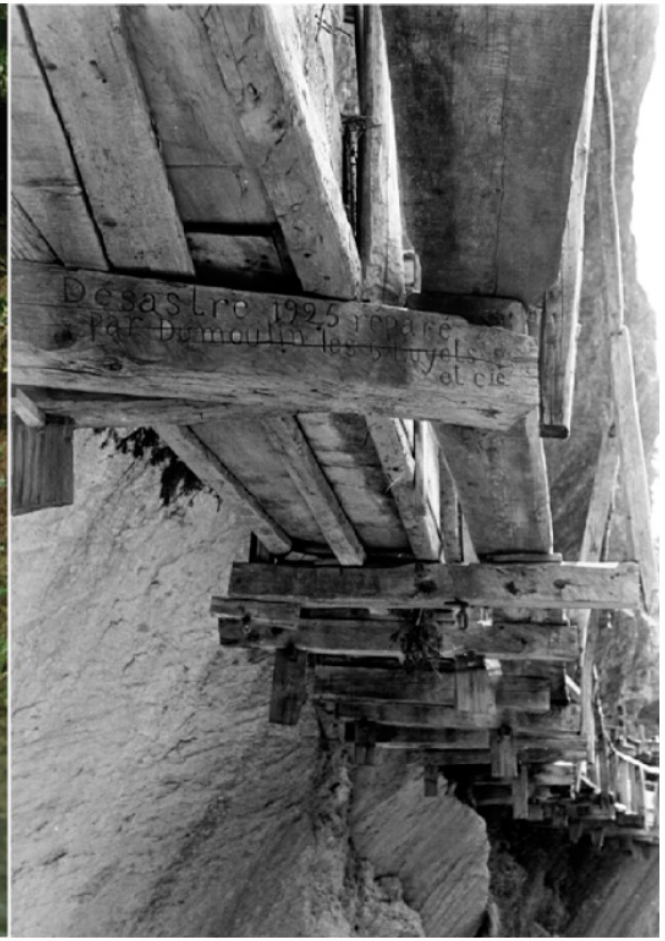
- > 1400 km of irrigation canals before 19th century



Source: Reynard, E. Hill irrigation in Valais (2002)

"Les Bisses"

Bisse of Ayent



Bisse of Savièse

Bisses network

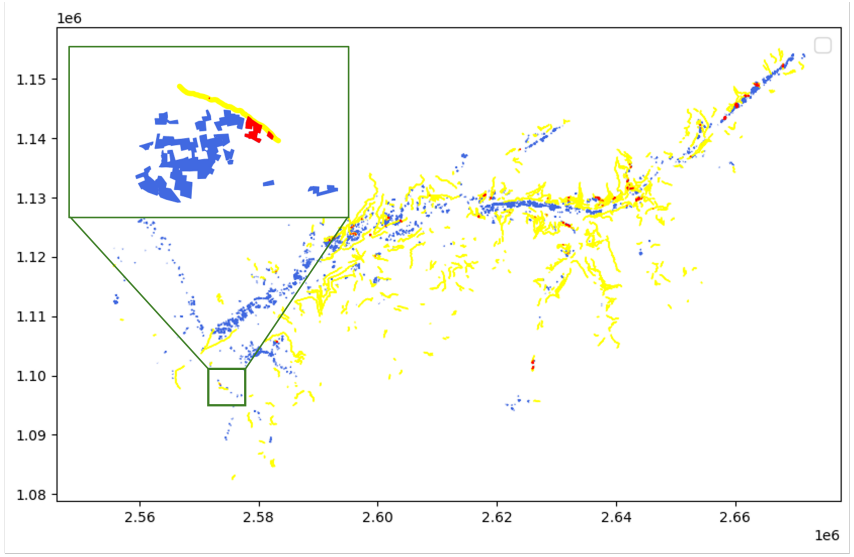


Figure 9: Bisses network (yellow), result of part 3.1 (blue), parcels intersecting a bisse (red). Total red area is 49 Ha

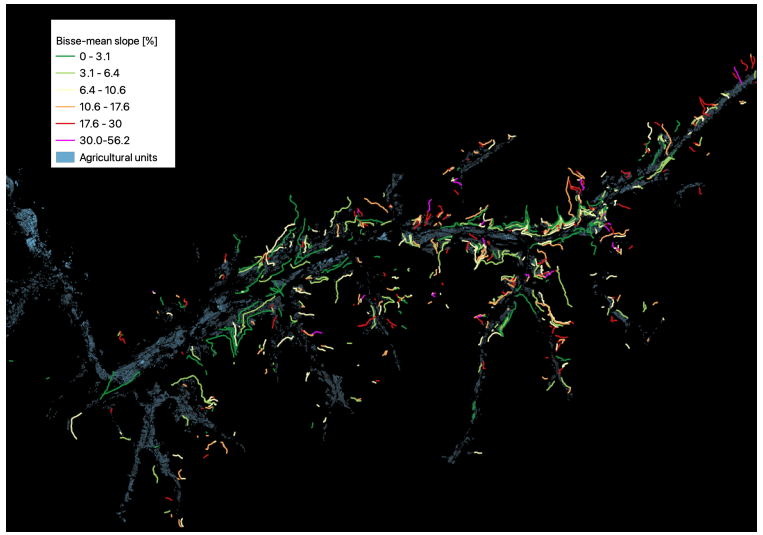
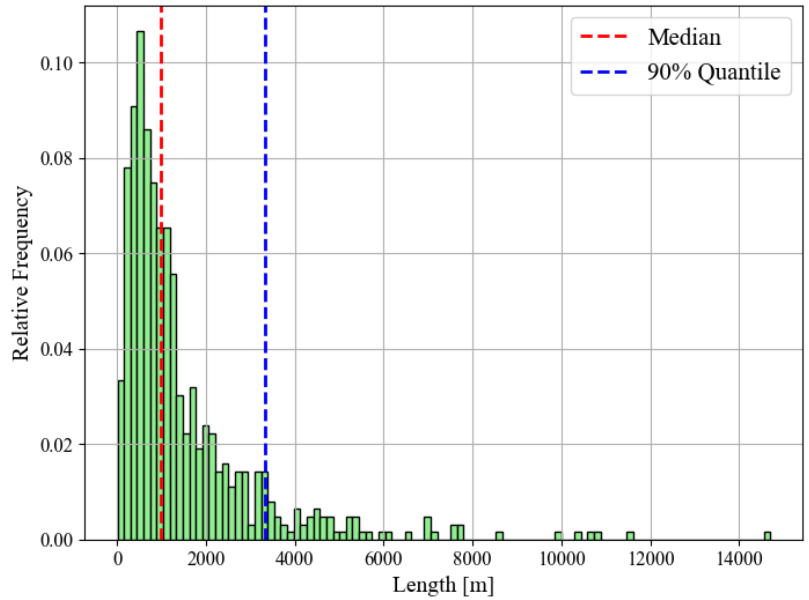


Figure 10: Bisses slope [%], calculated with their extremities altitudes and length



After J. Salles, 2024

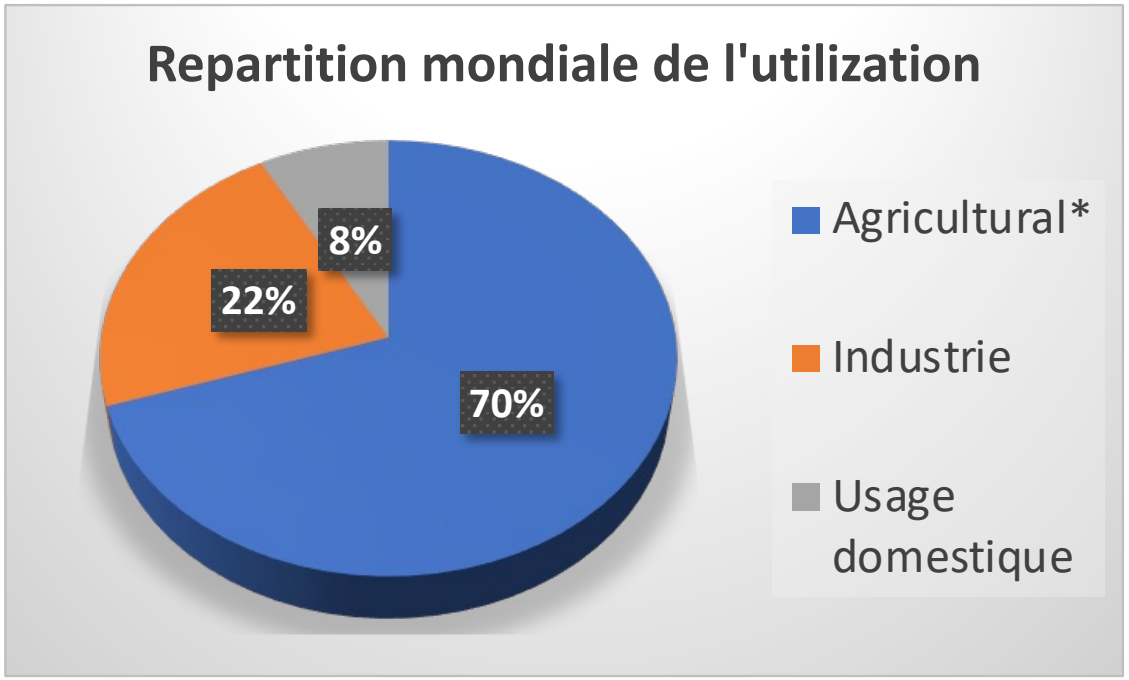
...and what about today?

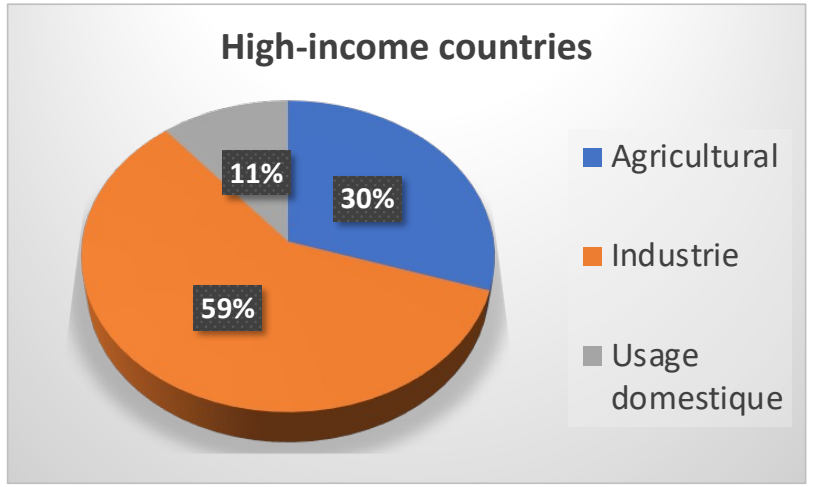
Urban agriculture seek to ameliorate the use of available land and resources under future changing scenarios.

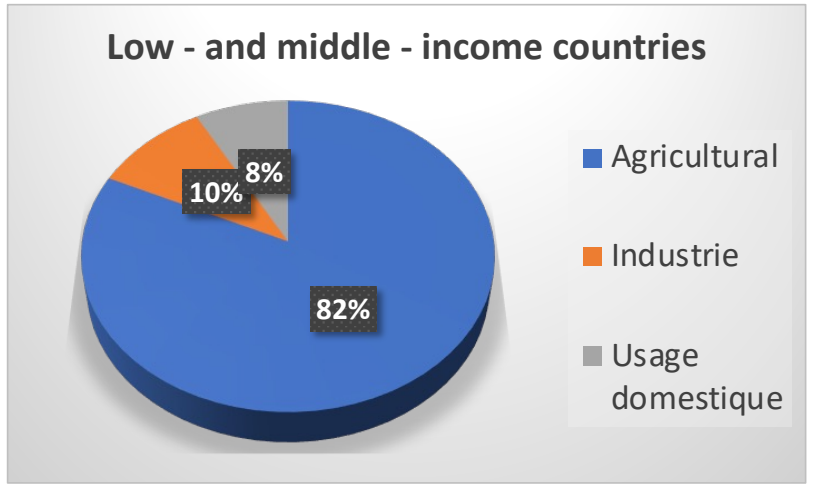
Its practice encompasses socioeconomic benefits as well as ecosystem services for the people and the environment

It presents important limitations and this creates challenges for future research

The state of water use in the world







* Asia: 82%; USA: 40%; Europe: 30%

The state of water use in the world (by country)

Table 1.1: Sectoral water withdrawals by region, rounded numbers (%).

Region	Residential	Industry	Agriculture
Africa	7	5	88
Europe	14	55	31
North America	13	47	49
Central America	6	8	86
South America	18	23	59
Asia	6	9	85
Oceania	64	2	34

Source: World Resources Institute (1998).

Compare the values above (25 ys old) with actual statistics and draft your conclusions

Water consumption per person per year has dramatically changed

350 cm → 1900

642 cm → 2000

However, the amount of available water today is more or less the same as when Mesopotamian civilization prospered

Increased consumption led to increased water withdrawal!

Definition and interest for irrigation

Irrigation: the artificial supply of water to crops to supplement natural rainfall; the aim is to create favourable conditions for production, in terms of both quantity and quality.

Of the 1.55 billion hectares of cultivated land (permanent cropland) in the world 17%, or around 270 million ha* are irrigated.

These irrigated areas provide more than 40% of the world's harvests.

Irrigated areas produce 2 to 4 times more than non-irrigated crops.

***(1 ha=10000 m^2), 270 Mha = about 65 times the size of Switzerland**

Land use statistics by country

https://en.wikipedia.org/wiki/Land_use_statistics_by_country , FAO original data

Rank	Country	Cultivated land (km^2)	Cultivated land (%)	Arable land (km^2)	Arable land (%)	Permanent crops (km^2)	Permanent crops (%)	Other lands (km^2)	Other lands (%)	Total area (km^2)	Date
—	**World**	17,235,800	11.6	15,827,534	10.7	1,549,600	1	131.701.100	88.4	149,000,000	2011
1	India	1,765,260	53.7	1,656,780	50.4	108,479	3.3	1,522,002	46.3	3,287,263	2020
2	United States	1,681,826	17.1	1,652,028	16.8	29,798	0.3	8,151,691	82.9	9,833,517	2020
3	Russia	1,265,267	7.4	1,248,169	7.3	17,098	0.1	15,832,975	92.6	17,098,242	2011
4	China	1,238,013	12.9	1,084,461	11.3	153,552	1.6	8,358,947	87.1	9,596,960	2011
5	Brazil	800,485	9.4	570,572	6.7	68,126	0.8	7,715,285	90.6	8,515,770	2011
6	Canada	519,205	5.2	429,355	4.3	49,924	0.5	9,465,465	94.8	9,984,670	2011
7	Australia	487,695	6.3	307,520	4.0	7,741	0.1	7,253,525	93.7	7,741,220	2011
8	Indonesia	478,055	25.1	247,598	13	230,457	12.1	1,426,514	74.9	1,904,569	2011
9	Nigeria	412,938	44.7	354,726	37.3	68,361	7.4	510,830	55.3	923,768	2011
10	Argentina	397,598	14.3	328,087	13.9	11,122	0.4	2,382,802	85.7	2,780,400	2016
135	Switzerland	4,461	10.8	4,213	10.2	248	0.6	36,816	89.2	41,277	2011
136	Mauritania	4,124	0.4	4,124	0.4	0	0	1,026,576	99.6	1,030,700	2011

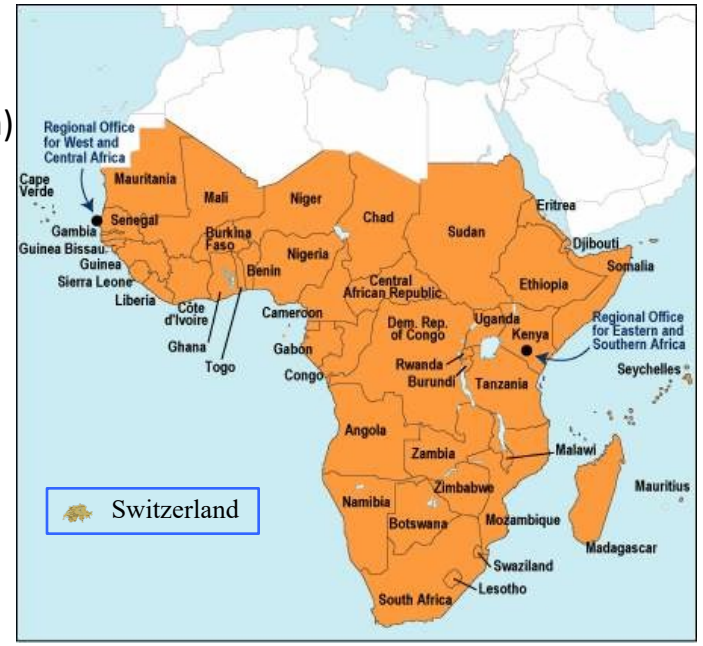
Evolution of world irrigated surfaces

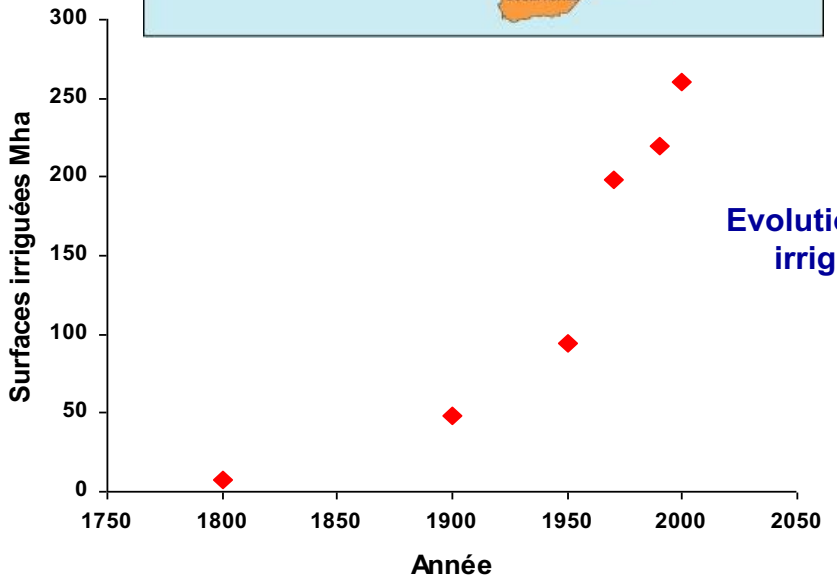
Country/Lands	Irrigated surface (million d'ha*)
India	57
China	50
USA	21
Pakistan	17
Middle East & Northern Africa	19
Sub-Saharian Africa	5
Latin America	14
Others	87
Total	270

(16Mha only the Indus Irrigation System)

Distribution régionale des zones irriguées

* Surface totale de la Suisse : env. 4 millions d'ha



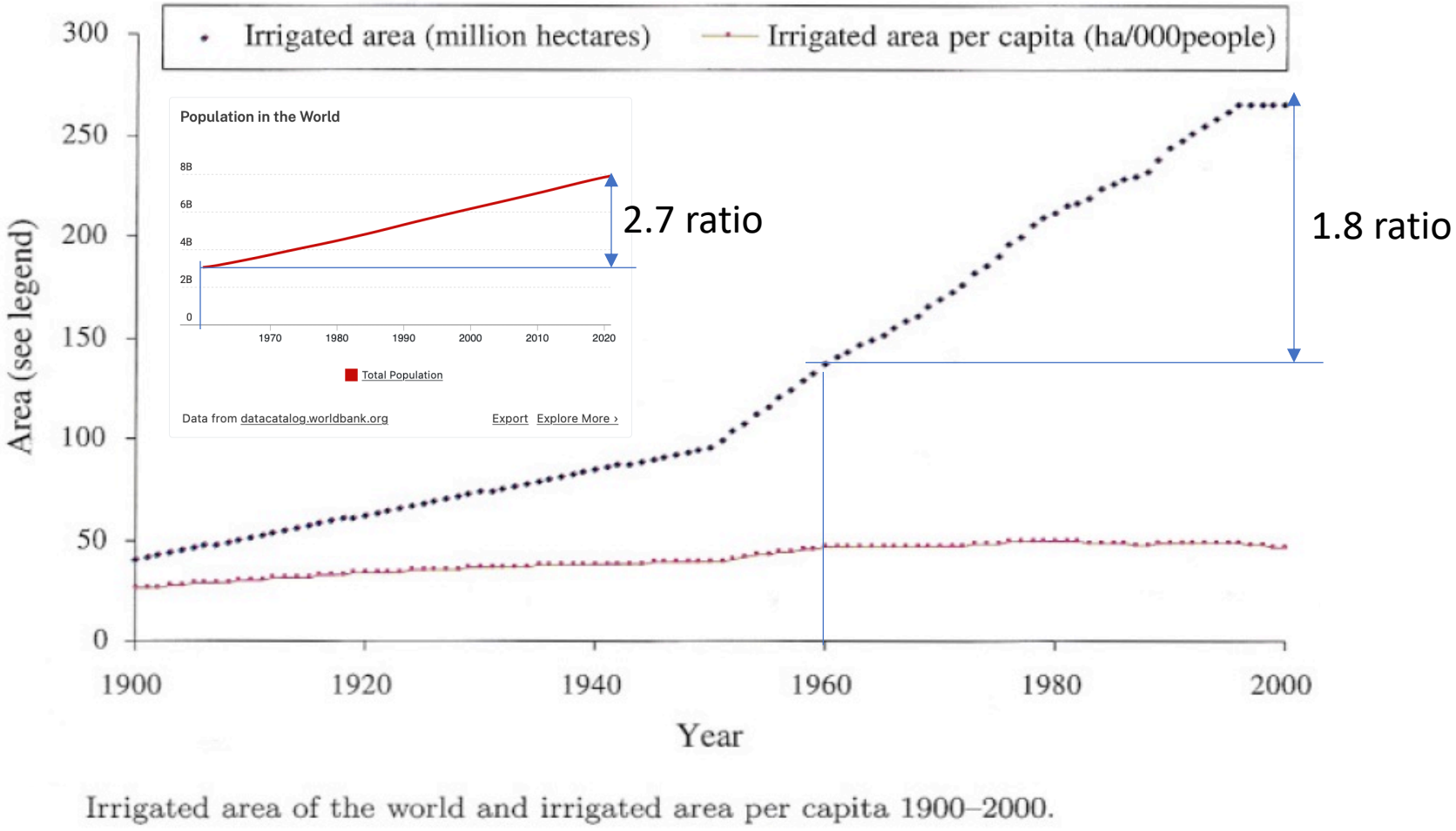


Evolution des surfaces irriguées dans le monde

Source ICID 2000

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)

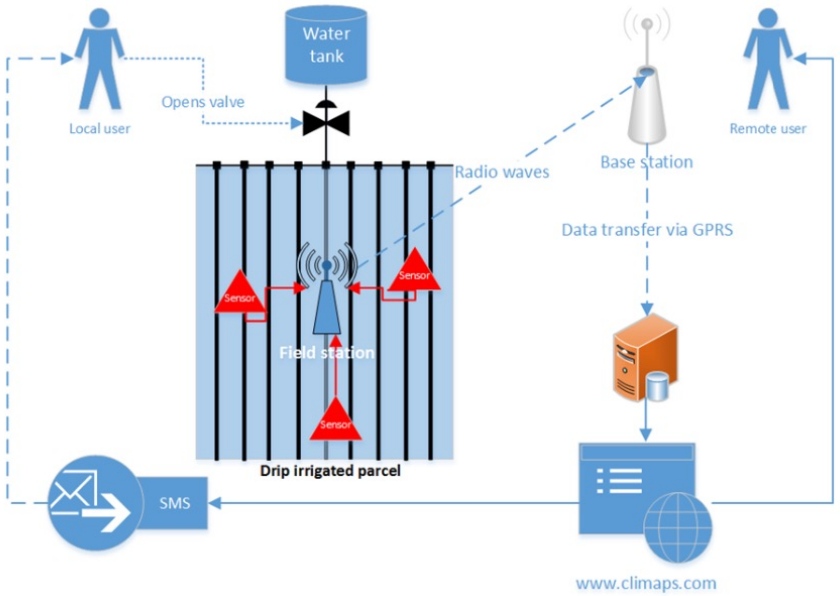
Facts

Agriculture (mainly irrigation) consumes around 70% of the world's freshwater.

World population: 80 to 85 million more people every year, mainly in arid and semi-arid areas.

The essential increase in food production will come mainly from irrigation.

Example: wireless sensor network system



➔ **Need to further improve irrigation efficiency, build new and sustainable irrigation networks, start using lower quality water and implement effective water conservation techniques.**

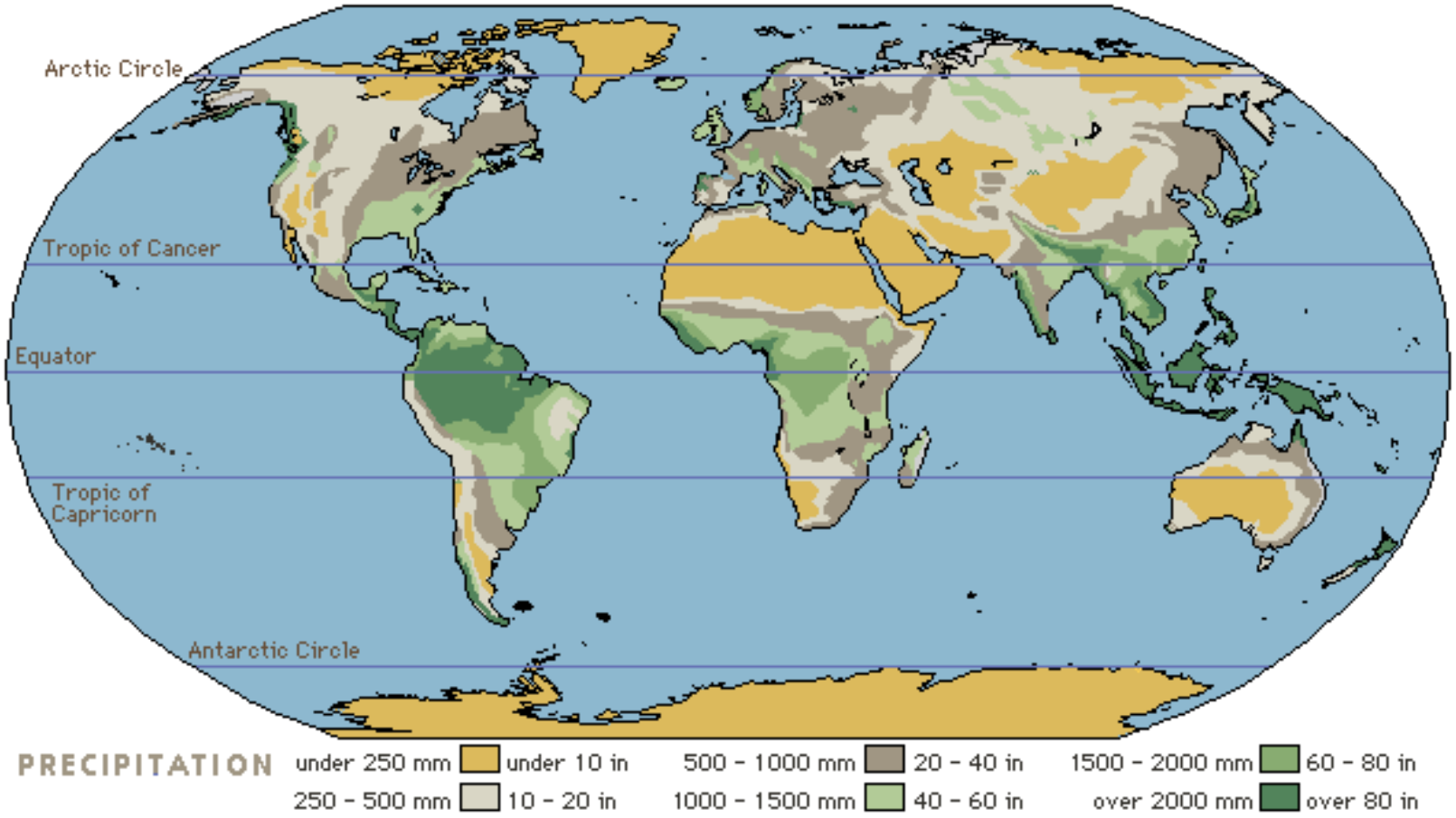
Fundamental vs complement irrigation

The artificial supply of water to crops to supplement natural rainfall determines two types of irrigation practices:

- **Fundamental or basic irrigation**
- **Complement or integrative irrigation**

Both practices strongly depend on local climate conditions and on precipitations' regime

Rainfall distribution across the globe

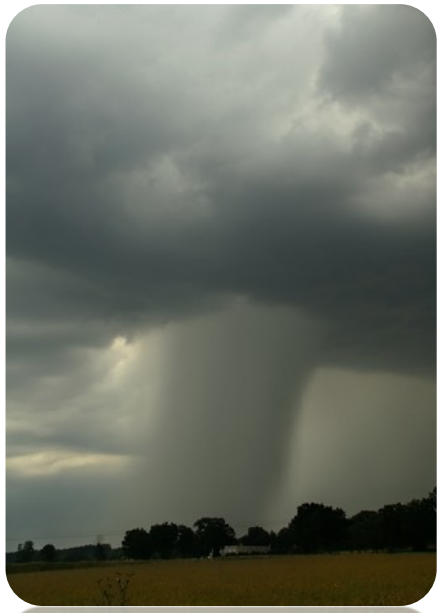


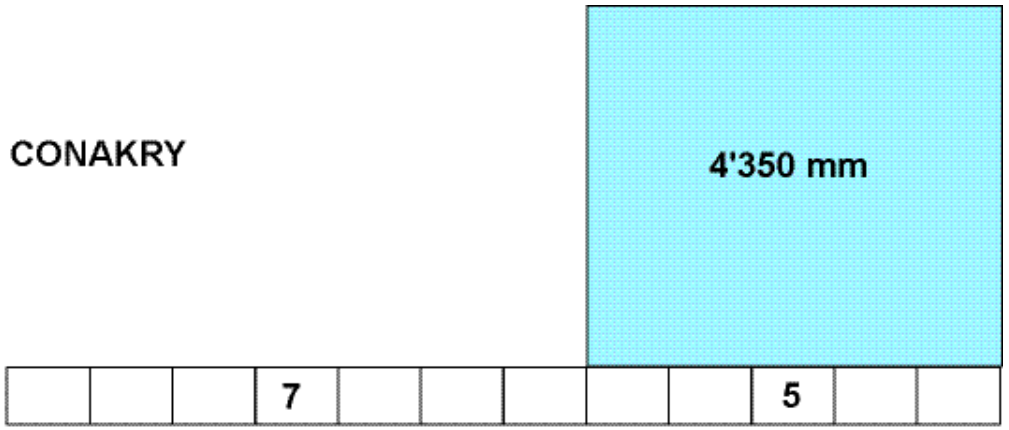
Mean annual global precipitation : 833 mm

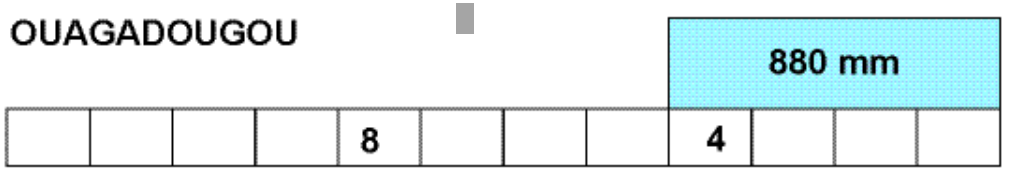
Highest values : in the equatorial zone (some Hawaii's islands: up to 10 m per year!)

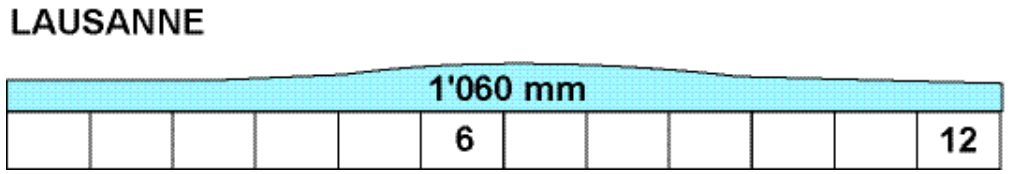
Lowest values : Arabian Peninsula, Northern Africa, Central Asia

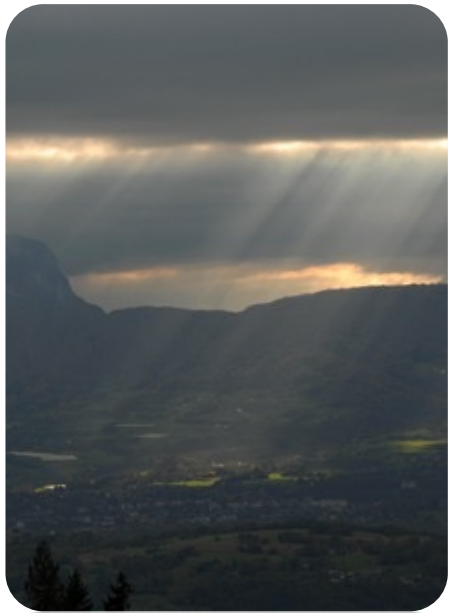
Example of mean annual temporal distribution (three sites)











Namibia
10-650 mm

South
Africa
100-700 mm

Main irrigation techniques

Surface or gravity irrigation (Flood, furrow, etc.)

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

Open channel flow hydraulics

Pressurized irrigation (e.g., sprinklers)

Water is pressurised and sprayed onto the crops in a similar way to rain, using appropriate equipment..

Pressure flow (turbulent)

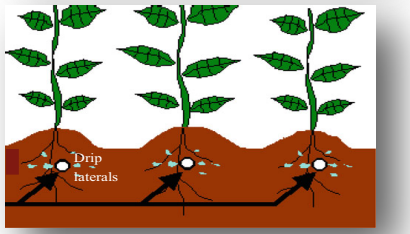
Localized, drip or micro-irrigation

Water is applied at low flow rates and frequent intervals, limited to the areas occupied by the plant roots; the "drip" system is the most commonly used.

Pressure flow (laminar)

Subsurface (sub)irrigation

Water is made available to the crop root system by upward capillary flow through the soil profile from a controlled water table.



Pressure flow (laminar)

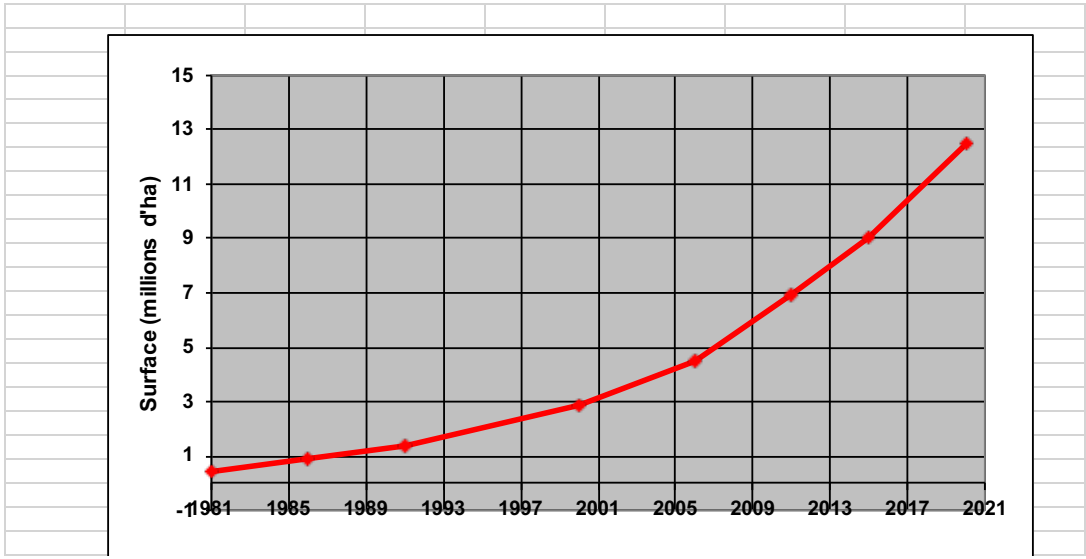
Relative use

Gravity irrigation accounts for more than 80% of irrigated land worldwide

Region	Gravity	Sprinkler	Micro
Africa	85	12.5	2.5
East and Middle East	88	11	1.5
USA	51	43	6

Area (%) covered by the 3 main irrigation methods

Micro irrigation is advancing quickly



Evolution of the total amount of surface using micro-irrigation