Irrigation and Drainage Engineering

(Soil Water Regime Management)

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4ETCS, Master option

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Lecture 13-2. Impact of drainage networks

Environmental impact

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Direct impacts

- On wetlands
- On the soil
- Surface water (quantity and quality)
- On groundwater (including the water regime of wetlands worth protecting)

Indirect impacts

- Changes in land use
- Impacts on health*

* water-borne diseases

Disappearance of wetlands

Ecotones, which fulfil a number of important functions in terms of :

- Biological: high biodiversity (plant species, birds, amphibians, fish, etc.)
- Hydrological: regulation of river flow, sediment deposition, groundwater recharge, water purification, etc.
- Economic: breeding of aquatic species, fishing, wicker production, etc.
- Social: landscape quality, places of discovery and recreation, etc.

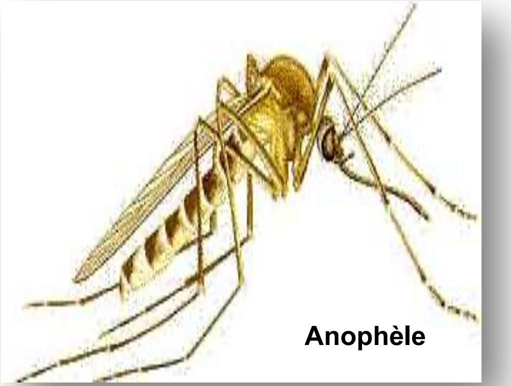
Should they be dried out?

Confrontation between agricultural gains and valuable ecosystems
Nowadays, inversion of tendency worldwide

Impact on vector-borne diseases

Diseases spread by intermediate hosts that live in water (molluscs that transmit schistosomiasis) or vectors (mosquitoes) that need an aquatic environment at certain stages of their development (anopheles that transmit malaria and simulia that transmit onchocerciasis).

Eliminating shallow areas of stagnant water (marshes, ponds, etc.) limits the proliferation of vectors and intermediate hosts and therefore the risk of spreading the diseases concerned.


Anophèle


Simulie


Mollusques

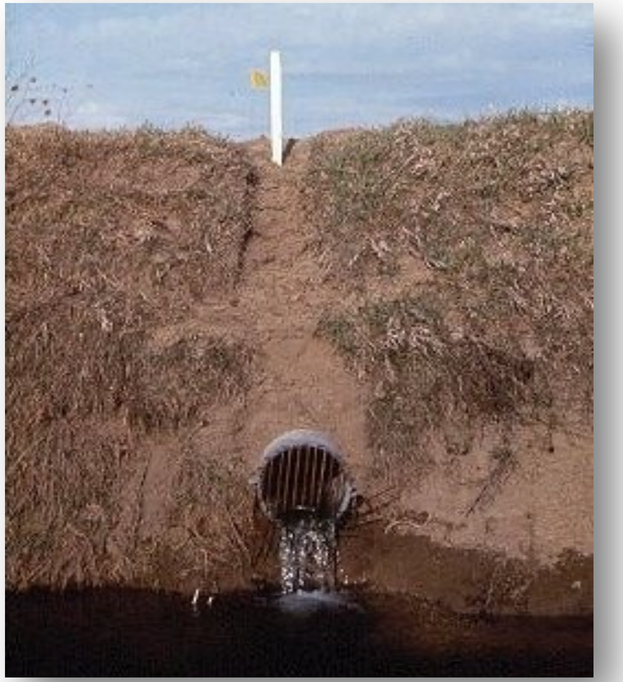
Positive impact of drainage on soil:

strong improvement in agricultural potential

- changes in the functional characteristics of the soil (aeration, thermal regime, biological activity, redox potential, etc.)
- in the medium and long term: improved soil structure, infiltration capacity and water circulation; new biological balance
- reduced operating constraints (access to plots, crop diversification, etc.)
- reduced risk of salinisation

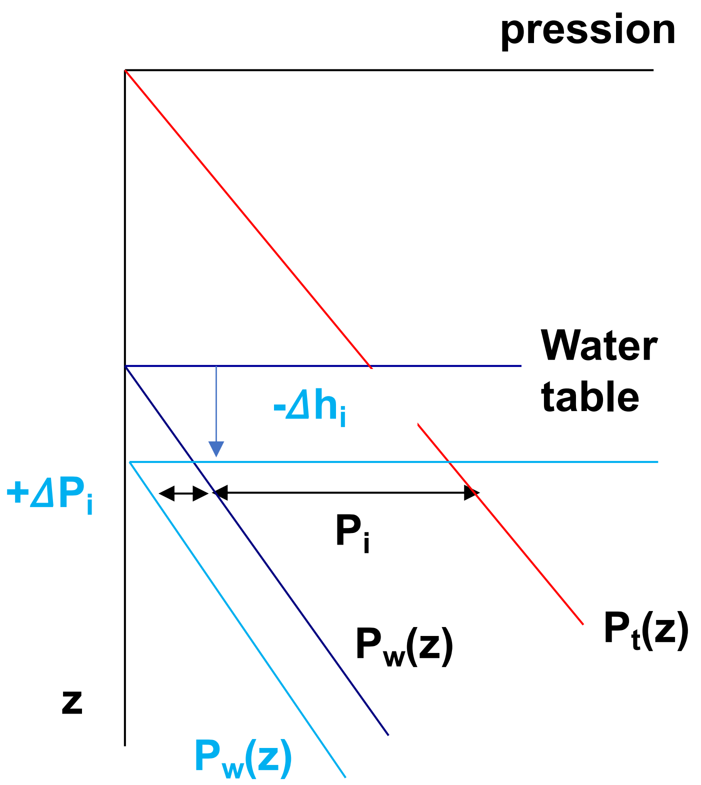
Possible negative impacts

- increase in intergranular pressure and compaction
- subsidence of peat soils



Increase in intergranular pressure

The intergranular pressure Pi characterises the pressure acting at the points of contact between soil particles. The higher Pi, the more compact the material.



$$P_i = P_t - P_w$$

P_t : total pressure caused by the weight of the ground* at the point considered = Weight/Surface

P_w : hydrostatic pressure

If the water table is lowered, Pw(z) undergoes a downward translation (it decreases) and Pi increases.

➔ Soil subsidence

The extent of compaction depends on the type of soil: the finer the soil, the more sensitive it is; soils rich in organic matter are the most affected.

* and, where applicable, other loads applied to the surface

Subsidence of peat soils

Three major causes:

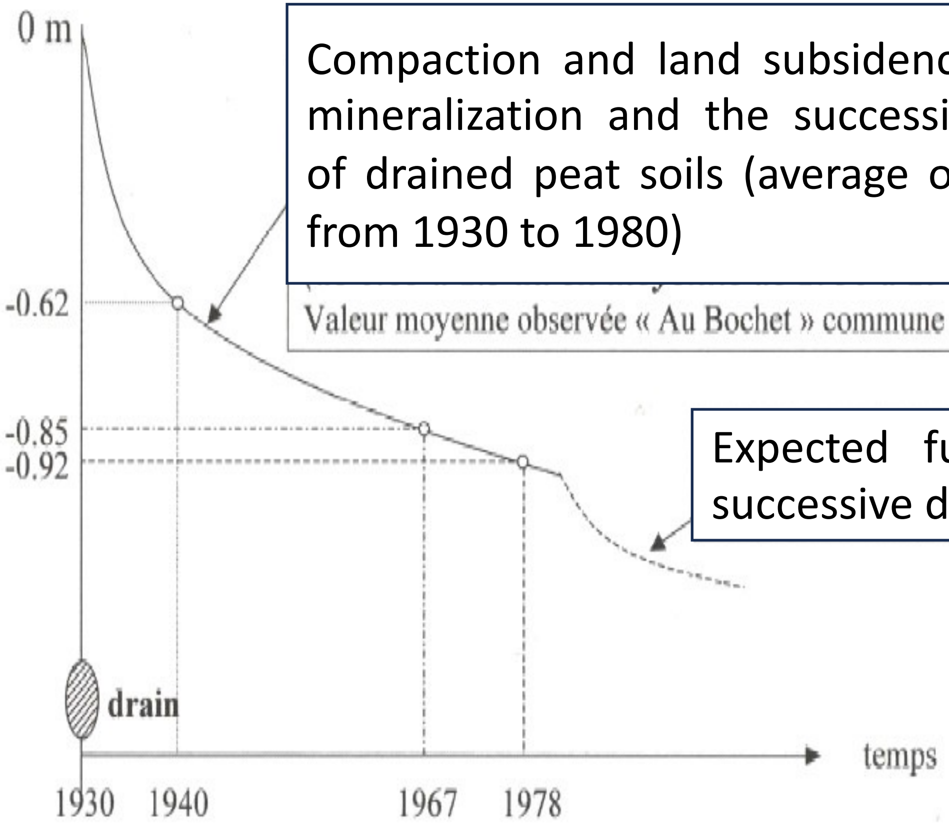
- oxidation of organic matter: transformation of organic carbon into CO_2 → accelerated mineralisation
- retraction: increase in intergranular pressure; in addition, increase in suction, and therefore capillary stresses
  → retraction of the solid matrix
- increased sensitivity to wind erosion.

Settling = f (type of peat, stage of decomposition, climatic conditions, crops grown and depth of water table)

From a few cm per year (0.5 to 2 cm) in temperate climates to several cm per year (up to 10 cm) in tropical climates.

Compaction and land subsidence following the mineralization and the successive compression of drained peat soils (average of 0.83 to 1.3 m from 1930 to 1980)

Expected further subsidence due to successive drainage



Example of soil compaction and subsidence in the Orbe plain

The rapid weathering of peat can be slowed by :

- appropriate management of the water table
- the use of appropriate farming methods (e.g. no-till)
- choosing crops that are resistant to flooding
- restoring the environment to its natural state

Quantitative impact of drainage on surface water

Influence of drainage water discharge as a function of:

- hydrological characteristics of the drainage area
- ratio of treated surface area to total surface area of the drainage area
- nature of the materials covering the drains

Two effects possible:

- increase soil infiltration capacity and reduce runoff
  - ➔ Reduced flood flows
- accelerated transfer of groundwater to the outfall
  - ➔ increasing flood flows

In most cases, particularly in large, low-slope catchments, the effect is moderating for high-frequency floods or negligible in the case of extreme floods.

In some small, relatively steep catchments, rehabilitated by drains topped by drainage trenches, flood flows can sometimes be seen to increase.

Impact on water quality

Composition of drainage water

- Highly exported elements: nitrates, chlorides, etc.
- Weakly exported elements : ammonium, nitrites, phosphorus, pesticides, etc.
- Intermediate elements: sodium, potassium, sulphur, etc. in certain types of soil (saline)

The quality of drainage water is highly variable, depending on climatic conditions, the environment and farming practices.

The composition varies greatly over time during a flood event, during the season and from one year to the next (depending on the climate and farming practices).

Pesticides

Pesticide entrainment is a function of:

- Quantity applied
- Timing of rainfall after application
- Pesticide characteristics (sorption, degradation, solubility, etc.)
- Soil characteristics (OM content, clay content, structure, presence of macro-pores, etc.)
- Depth of water table

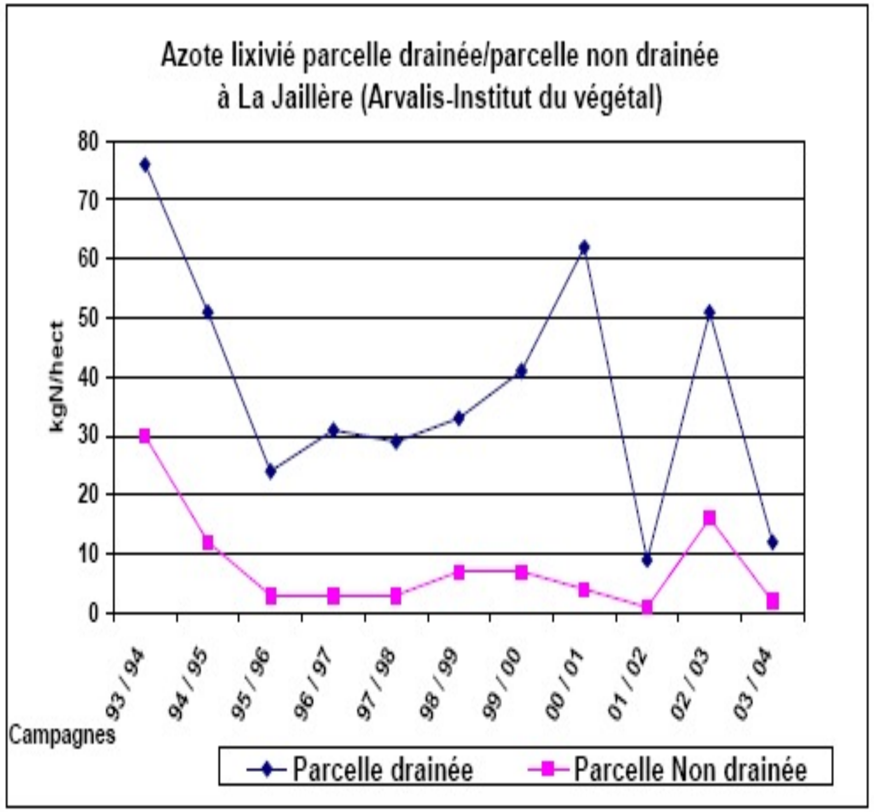
The proportion of the initial application released into the drainage water generally does not exceed 1%. After a few months, the substances are often no longer detectable in the drainage water.

Effects of drainage on the export of soluble substances

Frequently observed mechanisms:

- Reduction in phosphate and pesticide exports as a result of reduced runoff and solid transport at the soil surface

- Increased nitrate exports as a result of greater volumes of infiltrated water; sometimes, however, more intense biological activity stimulates mineralisation and absorption by crops.



Influence of drainage on nitrate discharges

Discharge of drainage water

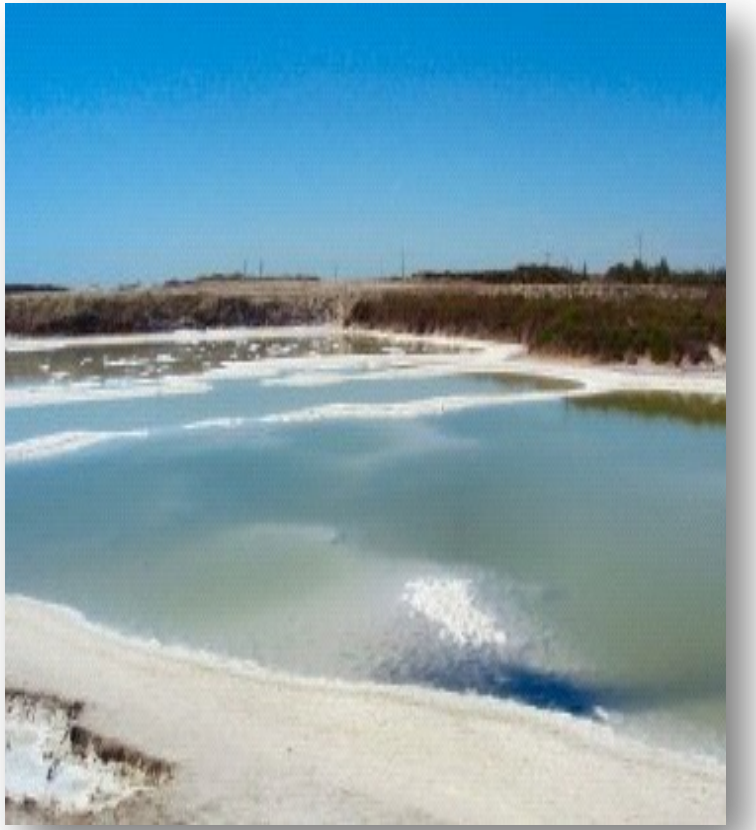
- Humid temperate climate: frequent discharge into the river system with risk of contamination by substances linked to intensive farming practices

- Arid and semi-arid climates: drainage often practised to prevent soil salinisation

  ✓ Discharge into the network: risk of contamination of the receiving environment

  ✓ Reuse for irrigation

  ✓ Discharge into evaporation ponds: problems include cost, loss of land, risk of infiltration and recycling of salts.



Evaporation pond

Reduced impact on wetlands to be protected

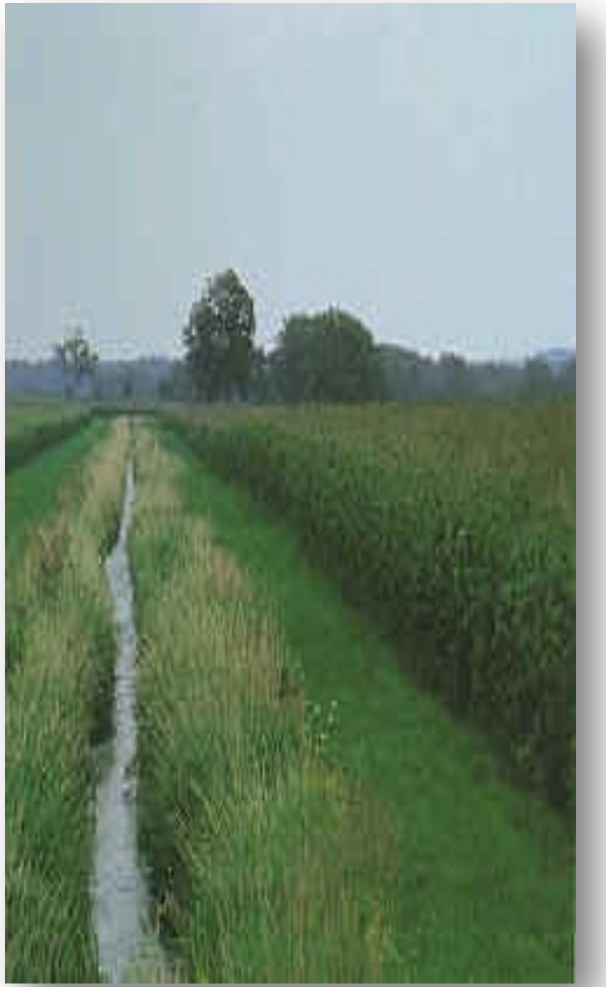
Creation of transition zones (buffer zones)

Intermediate zones to ensure a gradual transition between natural environments and used areas (agricultural zones, industrial zones, leisure areas, etc.).

The sizing of buffer zones involves a number of aspects:

- biological (safeguarding species diversity)
- ecological (preservation of biotopes)
- trophic (preventing contamination by plant protection products)
- hydrological (preventing the risk of drying up)

⇨ **Multidisciplinary approach**



Transition zones (buffer zones)

Agriculture - natural environment contacts

Main sources of disruption :

- Exports of fertilisers and plant protection products
- Changes in the water regime

Designing a buffer zone to prevent a harmful change in the water regime :

- empirical approach
- semi-empirical approaches
- physics-based approaches

Design of buffer zones

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- Empirical values : 30 < L < 300 m and more

- Semi-empirical approahces:

  $L = 200\ H\ K$

  L : Width of buffer zone (m)
  H : Drains depth (m)
  K : saturated hydraulic conductivity of the soil (m/j)

- Physically-based modelling:
  - *Drains laid on a low permeability layer*

$$L = 2.2\sqrt{\frac{K H t}{\mu}}$$

t : duration of the drying period(j)
μ : drainage porosity

$$L = \sqrt{\frac{8K(2d + H)\,t}{\mu(4 - \pi)}}$$

d : Hooghoudt's equivalent depth

Wrapping up: on irrigation and drainage projects

Environmental planning measures in irrigation systems

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Conception and construction phases

- plan as many straight stretches as possible
- choose an appropriate slope for the channels and banks
- carefully construct waterfalls, weirs, siphons, etc.
- provide sufficient bridges
- install leakage channels (periodic flushing)
- reduce seepage losses and provide an effective drainage system
- if necessary, install mollusc filters
- backfill areas where soil is borrowed
- Consider integration of regenerative agriculture techniques

In high-risk areas, where possible, lay a surface or use pipes*.

* earthen canals frequently the source of vector breeding sites: low bank stability, grass cover, siltation, high losses through infiltration hydromorphy

Operation and maintenance phase

- systematic maintenance of canals (cleaning, reshaping, clearing undergrowth, etc.) and specific structures
- precise adjustment of watering rates, doses and frequencies

If justified/considerate :

- periodic flushing
- alternating watering and draining
- Maintain environmental flows

Plot irrigation

- choice of an appropriate irrigation method
- short periods of submersion
- levelling of plots
- regular maintenance of the drainage network
- judicious choice of crops

Socio-economic impact of irrigation and drainage networks

Adjustment difficulties :

- familiarisation with irrigation techniques
- Excessive drainage (e.g., droughts changing scenarios)
- switch to intensive crops
- new cultivation techniques
- Mechanisation (reduces job availability)
- marketing, etc.

Causes of socio-economic problems

- inadequate planning and design
- deficiencies in management, operation and maintenance
- insufficient consultation, dialogue and empowerment of irrigators
- poor external support: professional training and supervision of users, availability of inputs and spare parts, access to credit, commercial outlets, etc.

➔ **Often disappointing performance (low efficiency and reduced yields)**

➔ **High potential for increasing efficiency and production**

Project success criteria

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- Technical relevance
- Social acceptability
- Economic viability
- Environmental acceptability

A sustainable project is one that is well-planned, well-designed, well-built, well-maintained and well-managed from a technical (hardware) point of view, and in which the operational (software) aspects are properly resolved in order to maximise the efficiency (low use of resources for high production).

« Sur le plan technique, c’est une réussite, sur le plan humain, c’est un génocide »

« In technical terms, it's a success; in human terms, it's a genocide.»

K. Zammiti, Sociologie d’un barrage (Sidi Salem)