ABSTRACT FORM

Controlled drainage with subirrigation: a management measure to discharge, retain and recharge fresh water

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Abstract

Sufficient freshwater is needed for water dependent sectors as agriculture, nature, drinking water, and industry. However, even in low-lying, flood prone countries like the Netherlands, climate change, weather extremes, economic growth, urbanization, land subsidence and increased food production cause an increased pressure on the regional groundwater system. Furthermore, the annual groundwater table in sandy soil areas dropped over the last decades with the effect that, nowadays, freshwater is becoming scarce in dry periods. Measures are needed to guarantee sufficient freshwater for all sectors. One of the solutions for the agricultural sector could be to modify the current pipe drainage systems (already existing in 34 % of the Dutch agricultural land) to drainage-subirrigation-systems. Doing so, subsurface drainage systems contribute to a shift in water management strategy: from drainage, to drainage, water retention and recharge.

We used data and model output of four experimental sites of the Dutch Pleistocene uplands, where controlled drainage with subirrigation is applied. Field data is collected over the years 2017-2021, like water supply, groundwater table and soil moisture content. All other water balance components, crop yield and configuration of the management of the systems are modelled with SWAP (Soil-Water-Atmosphere-Plant model).

Results show that through subirrigation water can be stored in the soil instead of being discharged. Water storage could raise the groundwater tables with ± 0.70 m during the growing season, leading to higher crop yields. By storing external water at the field scale, fast drainage was prevented, which decreased drought vulnerability. The effects of subirrigation on the water balance components are strongly site dependent. For example, a loamy layer below the drainage pipes is needed for enough resistance to fast downward seepage and to raise the phreatic groundwater level. Furthermore, ditch levels surrounding agricultural fields need to be adjusted to the raised groundwater levels, as too low ditch levels result in (unfavorable) lateral drainage. Field experiments also show that proper management of these systems is important to prevent clogging.

As conclusion, the construction, topographical location, and a proper management are important for subirrigation to be successful. Subirrigation could significantly alter water balance components, including the required water supply. Therefore, responsible implementation of subirrigation in the regional water balance is needed. However, if boundary conditions are met, controlled drainage with subirrigation could raise the groundwater level and improve the soil moisture conditions for crop growth, while still having the option to discharge water when needed.

Keywords*:* Drainage, (sub) irrigation, drought mitigation, water retention, water logging, drainage water management.

Indicate preferred presentation*: Oral* ~~or poster~~

Indicate the number of the scientific topic in case of oral/poster presentation.

1. *Soil and water conservation challenges*
2. ~~Soil functions and soil health~~
3. ~~Changes in hydrological pathways~~
4. ~~Best farming practices~~
5. *Monitoring, modelling and planning tools*

NIBIO
NORSK INSTITUTT FOR BIOØKONOMI

Congress: Soil and water conservation under changing climate in Northern or high-altitude conditions.
Session: Soil and water conservation challenges

4th May 2022, Campus Ås, Vitenparken, Norway

Controlled drainage with subirrigation

A management measure to discharge, retain and recharge fresh water

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programma Lumbricus KLIMAP
WAGENINGEN UNIVERSITY & RESEARCH
KnowH2O

KWR

Bridging Science to Practice

Small introduction

- Janine de Wit (MSc.)

- Researcher – KWR Water Research Institute, Nieuwegein, NL
- PhD Student – Wageningen University, The Netherlands

→ Scientific, applied research in the water sector.
  - Unsaturated zone – groundwater
  - Drainage systems – fresh water system
  - Agricultural and drinking water sector and the nature
  - Data collection (field work)/ data analysis/ modelling

Photo by KWR

KWR

Today

Session: Soil and water conservation challenges

Controlled drainage with subirrigation

Photo by Jon Mensink

Photo by Gé van den Eertwegh

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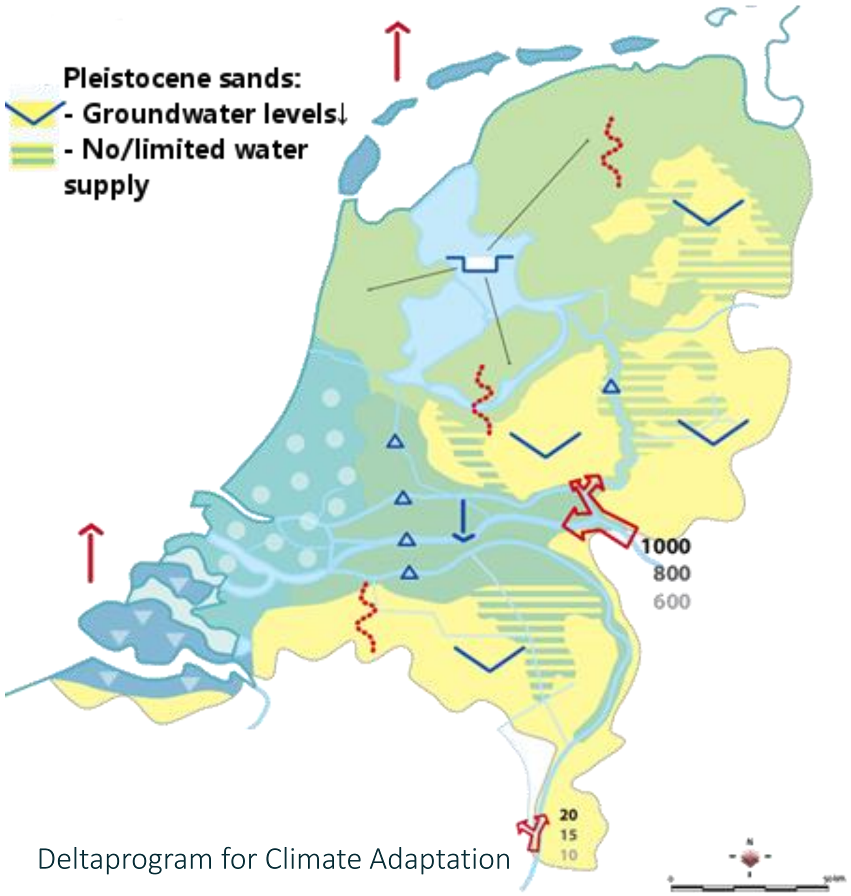
Challenges in the Netherlands

Balance between 1) water demand and water supply & 2) discharge and retention

- Climate change, freshwater availability, …



Deltaprogram for Climate Adaptation

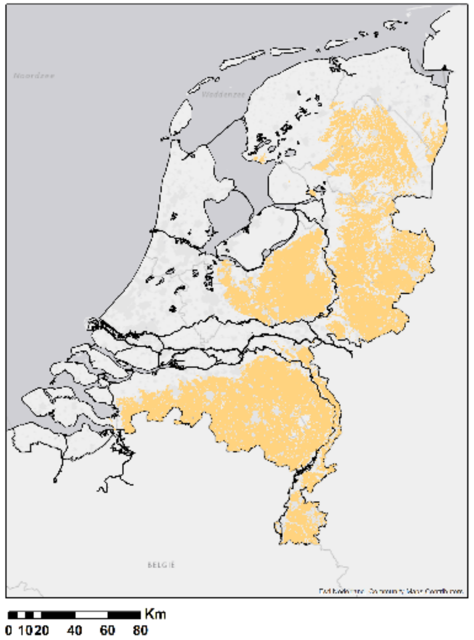
www.stowa.nl/lumbricus | Bartholomeus et al. (red) (2021)

Bartholomeus (red.), R.P., 2021. Programma Lumbricus - Integrale benadering van een klimaatrobuuste inrichting en beheer van stroomgebieden. Een overzicht. STOWA 2021-05. Stichting Toegepast Onderzoek Waterbeheer, Amersfoort.

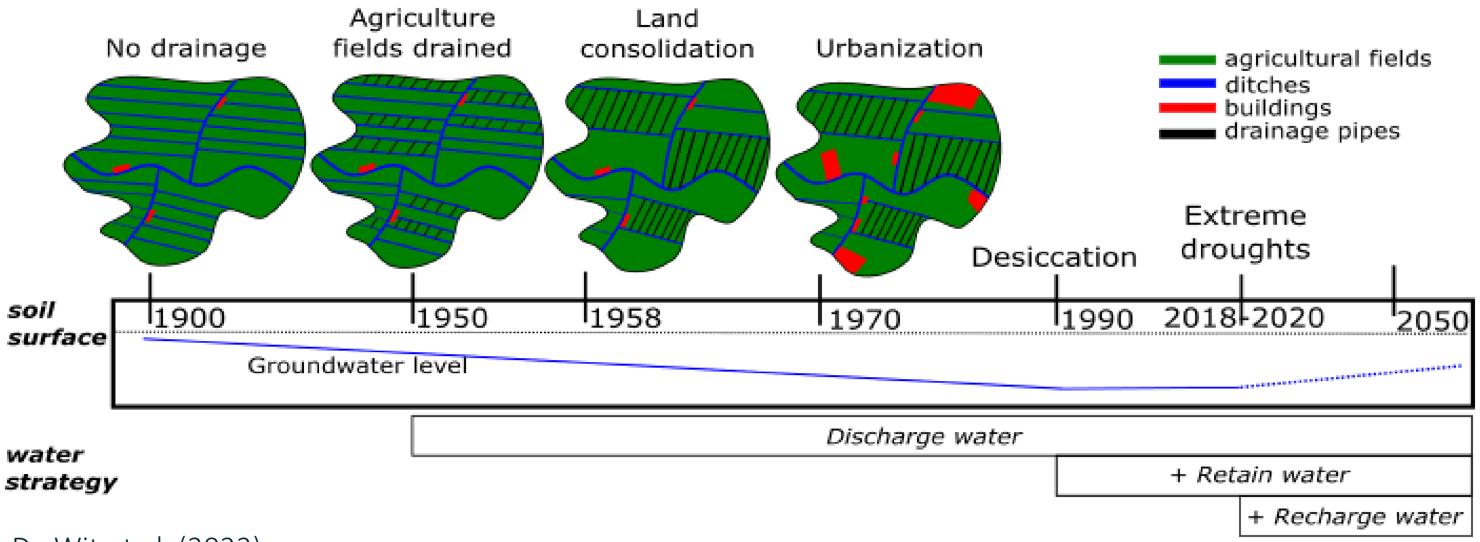
Developments in the Netherlands (1950-2020)

Impacts on the landscape design and the groundwater level

- Drainage, land consolidation, urbanization, economic growth, increased food demand, climate change, weather extremes
- Drainage: only when needed
- Retain and recharge when and where possible



De Wit et al. (2022)



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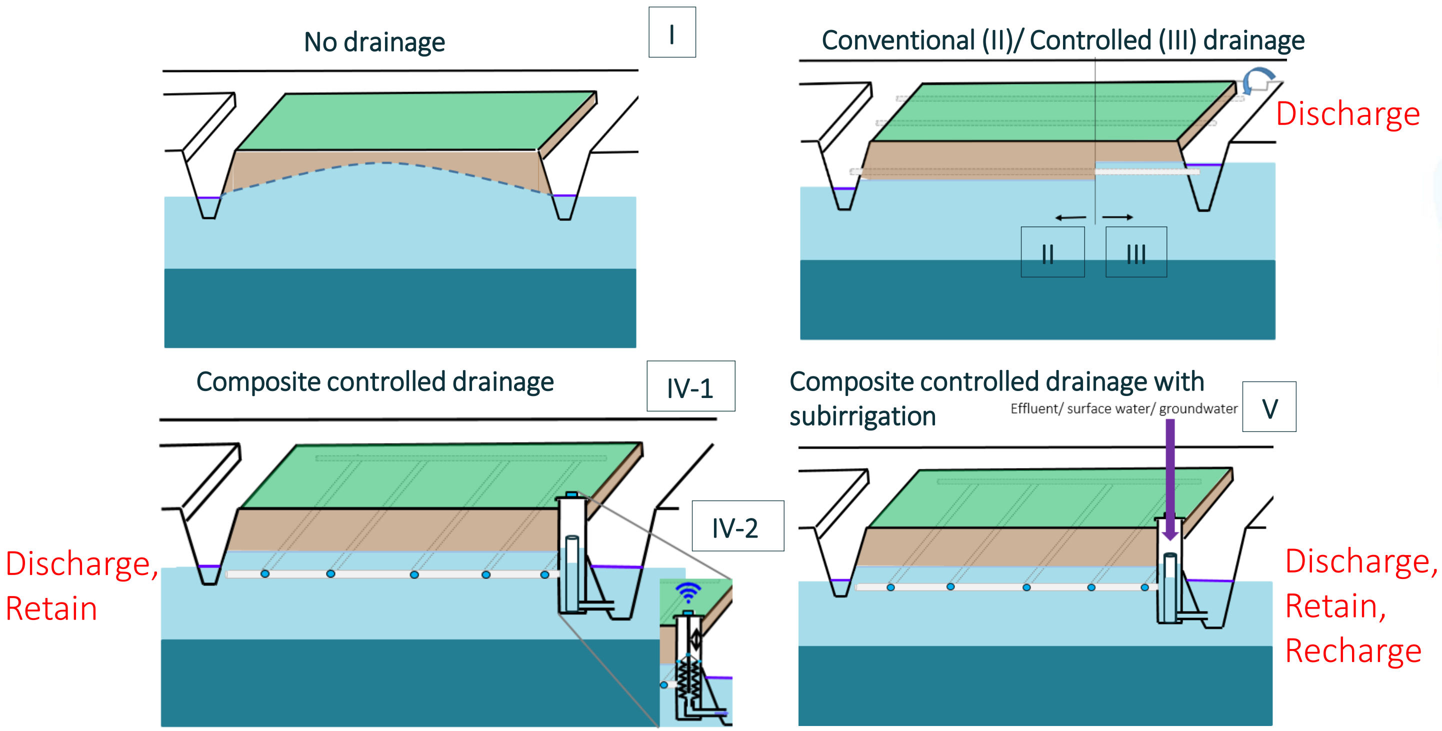
Discharge – retention – recharge

Example: controlled drainage and subirrigation

- Current controlled drainage systems → controlled drainage system with subirrigation



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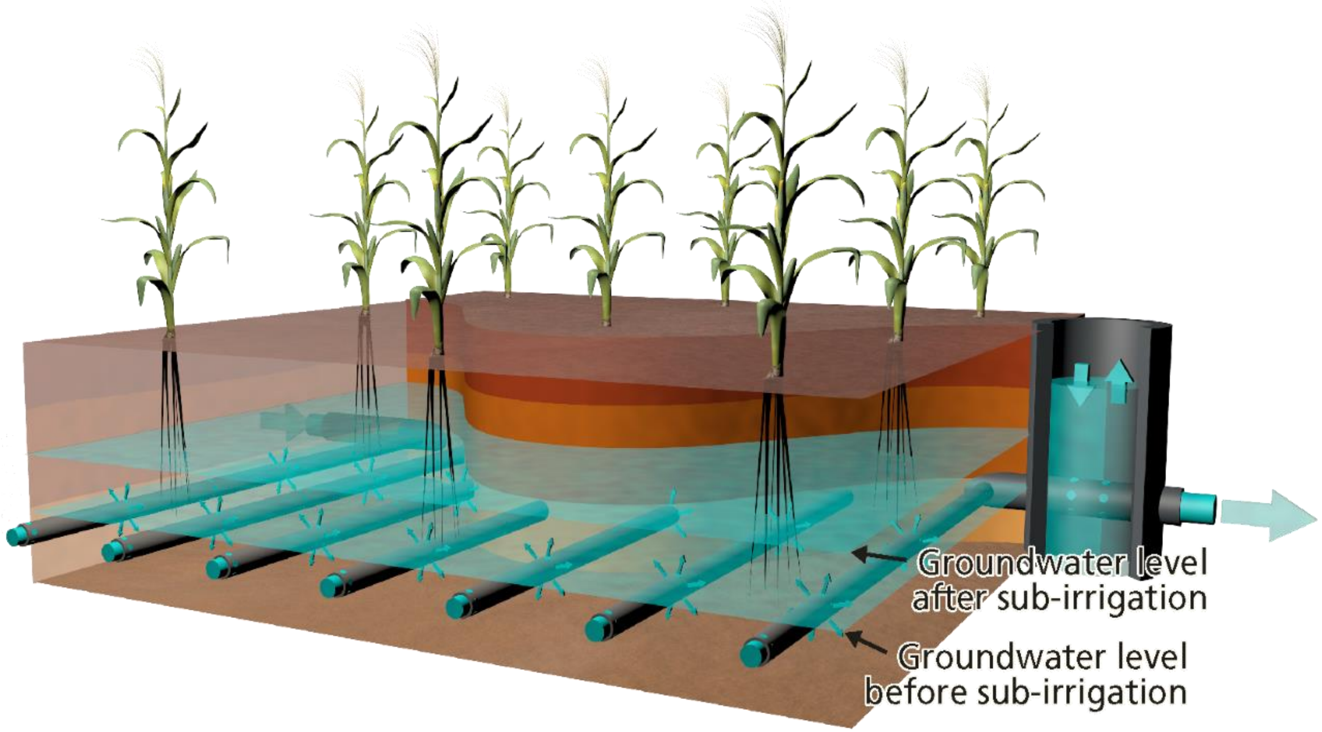
Agricultural water supply
Active supply through subsurface irrigation

- Water supply through controlled drainage system
- Goal: raise groundwater level for optimal soil moisture availability
- Success depends on continuous water supply
- Climate Adaptive Drainage (CAD) with subirrigation:
  Measurements + weather forecast + model calibration →
  required drainage crest level for optimal groundwater table
  (van den Eertwegh et al. (2013) and Bartholomeus et al. (2015))



Narain-Ford et al. (2020)

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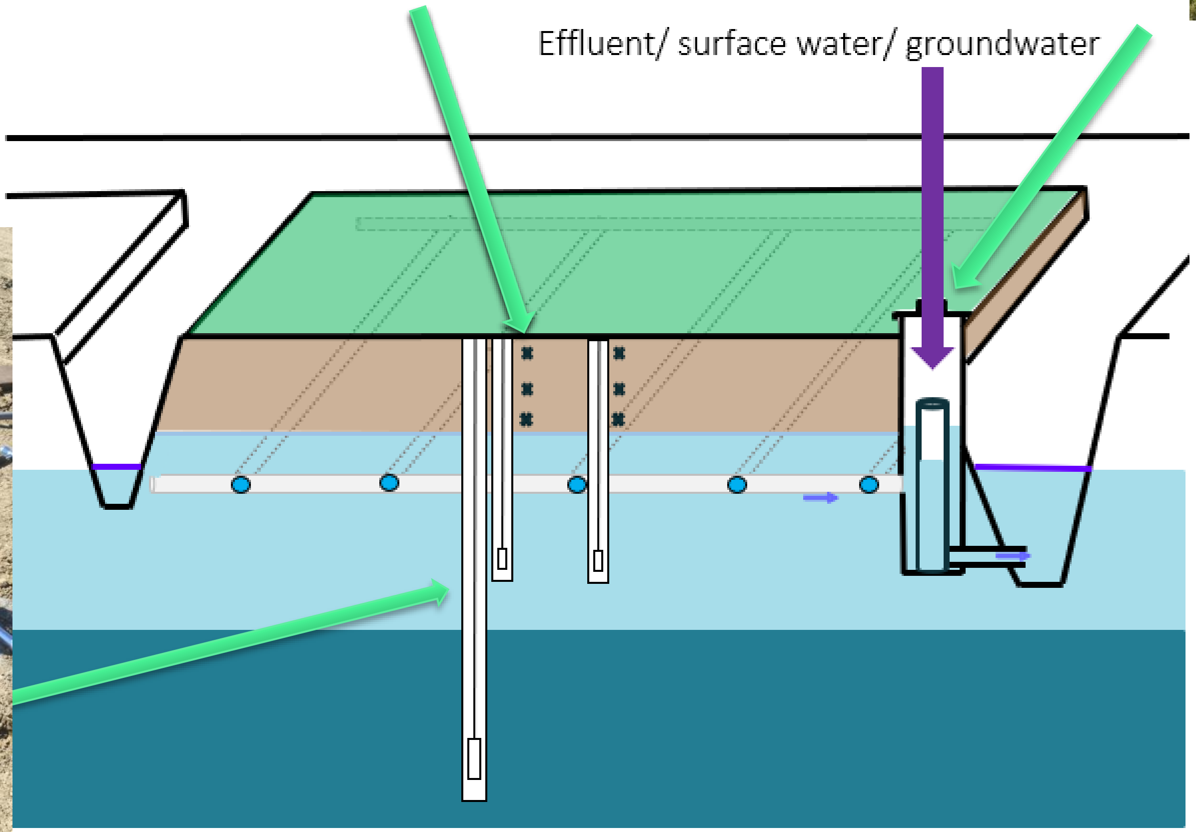
Field experiments in NL

Subirrigation

- 4 field sites with controlled drainage with subirrigation



Photos by Janine de Wit

Field experiments – sub-irrigation

Comparable experiments, some different characteristics

Stegeren (Ov)

Lieshout / Bavaria (NB)

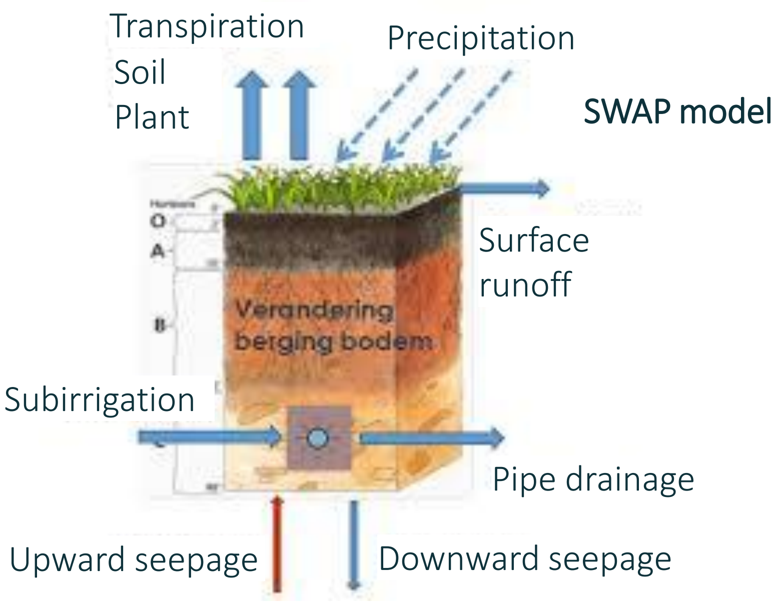
Haaksbergen (Ov)

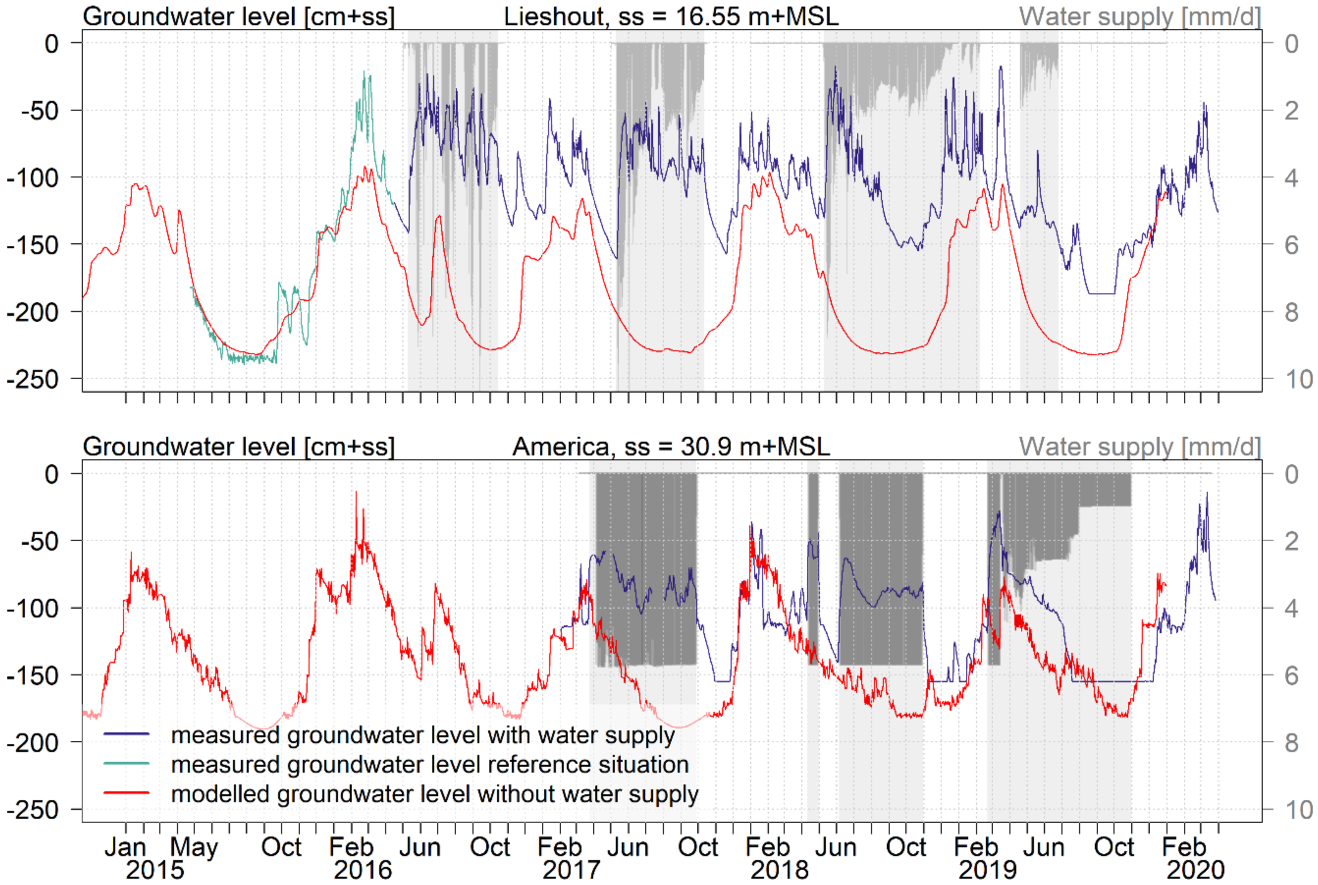
America (L)

		Stegeren (Ov)	Lieshout (NB)	Haaksbergen (Ov)	America (L)
Water supply source		Surface water	Treated waste water (industry)	Treated waste water (domestic)	Groundwater
MxG	MHG [cm-ss]	± 80	± 100	± 25	± 90
	MLG [cm-ss]	± 120	± 230	± 100	± 180
Soil		Sand, loam - none	Sand, Loamy layers > 1 à 1.5m	Sand, Loamy layer ± 30 cm > 3m	Sand, Loamy layer ± 20 cm > 2.20m

Results – groundwater level

- Groundwater level raises through subirrigation with ± 100 cm
- The groundwater level + effects could be reproduced by modeling





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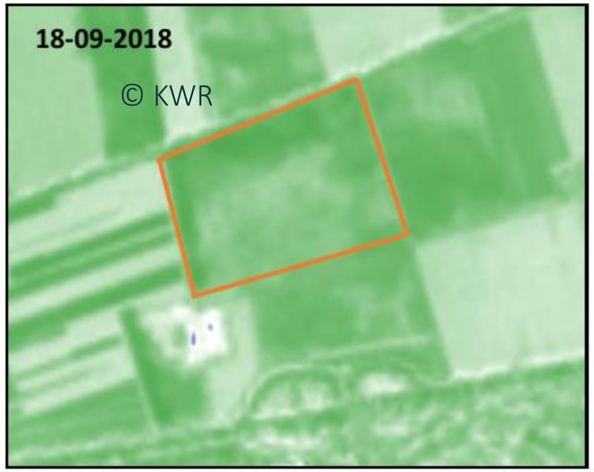
Results – soil water potential

- The soil is wetter with subirrigation than without
- Most effect at 60 cm-ss, then 40 cm-ss, then 20 cm-ss



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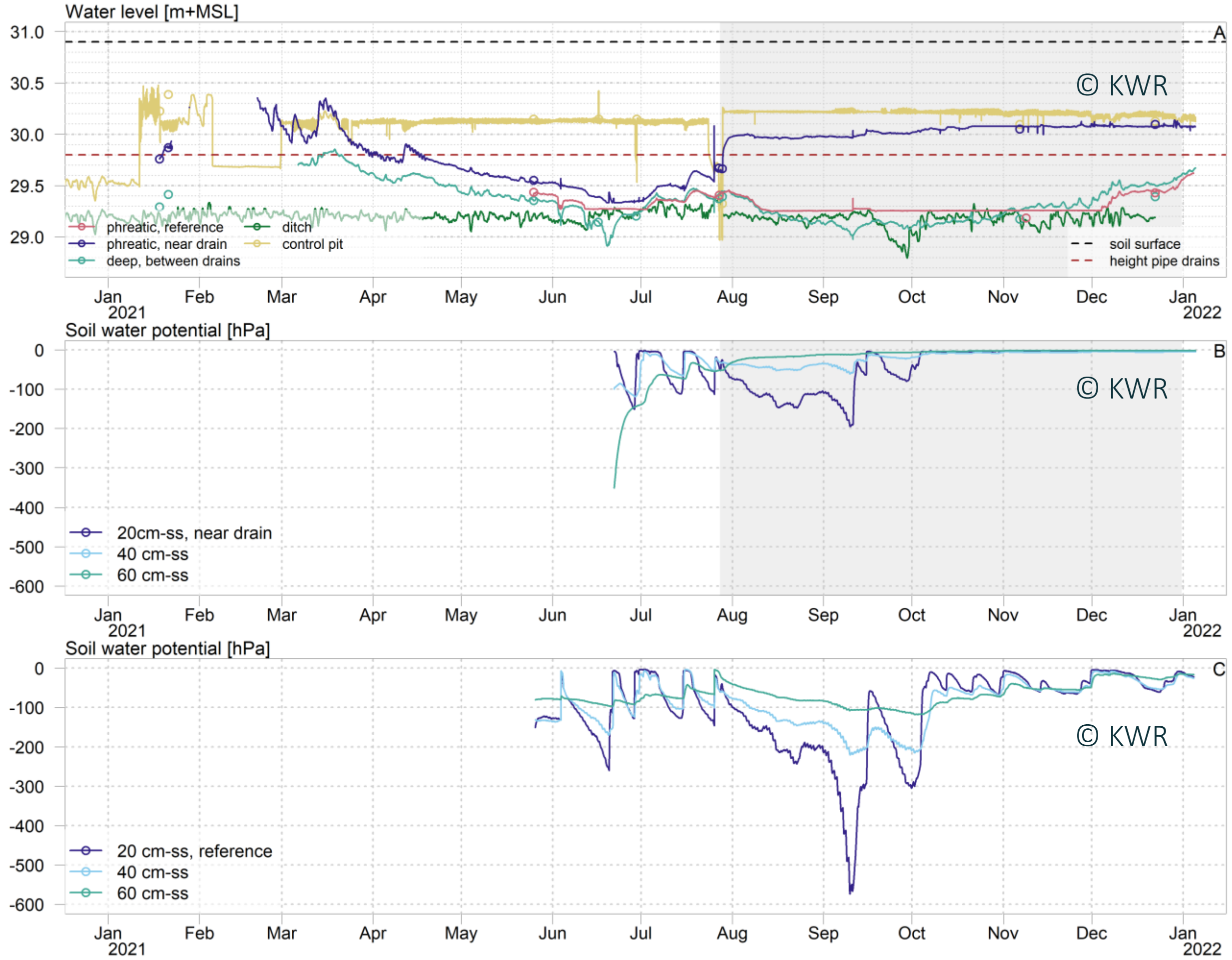
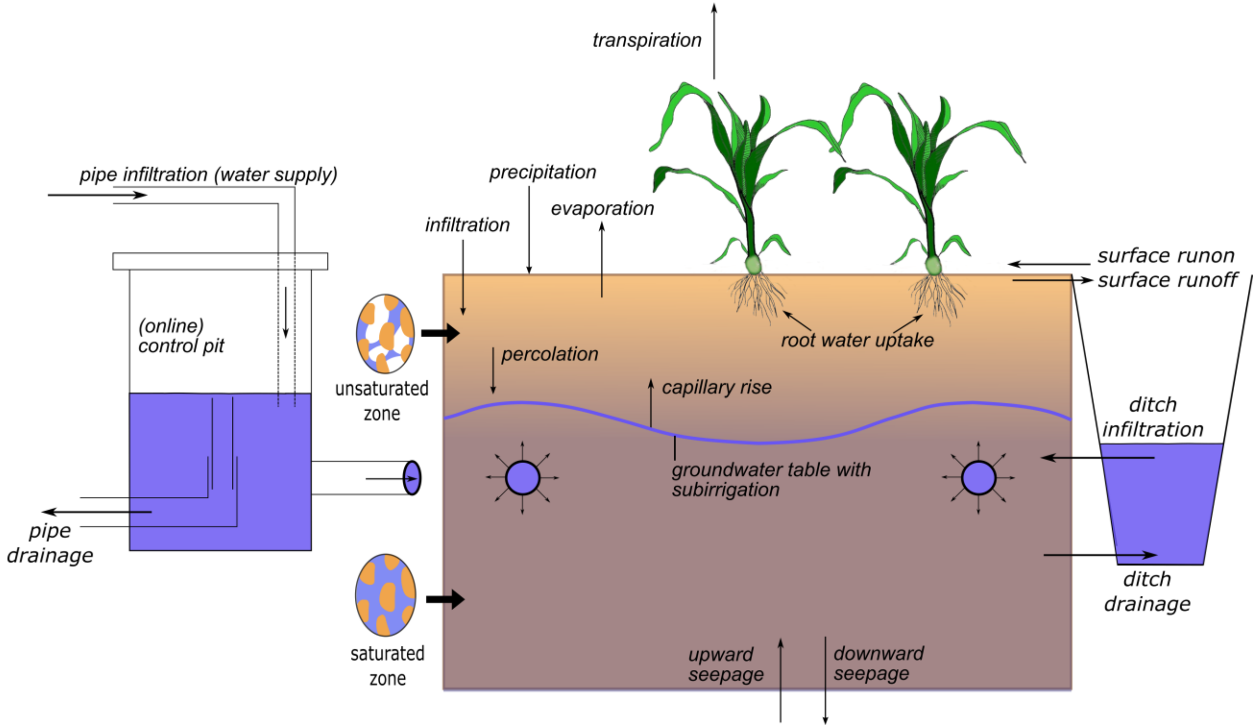


Results – The water balance

- Controlled drainage with subirrigation requires water
- Subirrigation alter the water balance components



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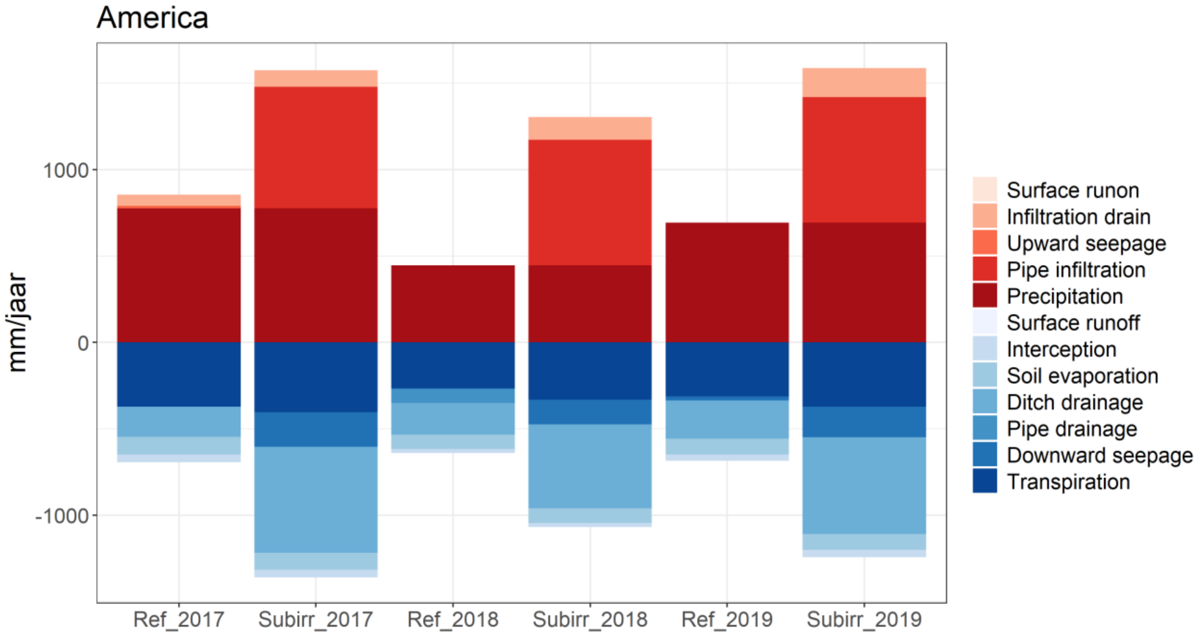

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Controlled drainage with subirrigation internationally

- Drainage systems are commonly applied in the world

- General observations
  - Pipe infiltration ↑
  - ETact (depends on GWL) ↑
  - Downward seepage ↑

Reference	Country	Soil	Groundwater table		Crop		Water supply		Water source	Drain characteristic	
			No sub (m-ss)	Sub (m-ss)	Yield (%)	Type (-)	Amount (mm)	Period (d)		Spacing (m)	Depth (m)
Hooghoudt (1952)	NL	Heavy clay	1.0	0.40/ 0.45	+ 84	Hay	4 mm/d	100	Surface water	2.0	0.6/ 0.8
Massey et al. (1983)[a]	Site 1 /USA	Loamy sand	–		–	–	227[a]		–	40	1.0
	Site 2 /USA	Loamy sand	–		–	–	171[a]		–	30	1.0
	Site 3 /USA	Loamy sand	–		–	–	296[a]		–	15	1.0
Doty and Parsons (1979)	USA	Sandy loam		0.6 higher	[b]	–	410 (1975), 260 (1976)	135	–	32	1.2
Smith et al. (1985)	USA	Sandy loam	1.0[c]	0.70	–	–	305.1	135	Surface water	15	1.0
Drury et al. (1996)	Canada	Clay loam	1991: 1.22, 1992: 0.92, 1993: 1.30, 1994: 1.10	1991: 0.95, 1992: 0.55, 1993: 0.60, 1994: 0.50	–	–	109 (1991, 1993, 1994) 5.7 (1992)[d]	±76	Irrigation pond	7.5	0.6
Fisher et al. (1999)	USA	Silt loam	–		7 (1995), 45 (1996)	Corn	–		–	5	0.75
Mejia et al. (2000)	Canada (1995)	Silt loam	1.30	0.91[e]	+ 13.8	–	223	–		18.3	1.0
	Canada (1996)		1.21	0.75	+ 6.6	–	248	–			
Ng et al. (2002) and Tan et al. (1999)	Canada	Sandy loam	1.31	0.82	+ 64	Corn	183.9	60	Surface water (lake)	6.1	0.60
Allred et al. (2003)	USA	Clay	–		Dry years + 34.5 + 38.1 Wet years + 14.4 + 9.7 Average + 19.6 + 17.4	Corn Soybeans Corn Soybeans Corn Soybeans	–		Re-use runoff water	2.4–4.9	0.76–0.91
Hornbuckle et al. (2005)[f]	Australia	(clay) loam	0.3 higher				143	17	–	36	1.8–2.2
Wesström et al. (2014)[f]	Sweden	Sandy loam	0.30–0.70		+ 6–10 + 20	Potatoes Wheat	2002: 60 2003: 80	–	–	16	1
Jouni et al. (2018)[g]	Iran	Silty clay	1.11	0.71	+ 27	Wheat	731	±242	–	80	2.0

De Wit et al. (2022)

De Wit, J.A., Ritsema, C.J., Van Dam, J.C., Van den Eertwegh, G.A.P.H., Bartholomeus, R.P., 2022. Development of subsurface drainage systems: Discharge – retention – recharge. Agricultural water management. DOI: 10.1016/j.agwat.2022.107677

Work in progress

Stegeren case in KLIMAP Project

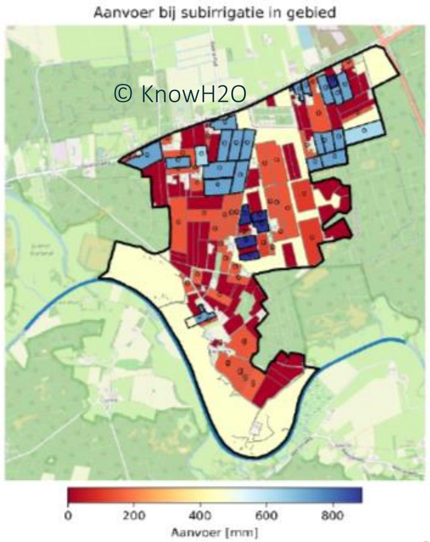


Figure by Wilco Terink

Photo by Janine de Wit

Photos by Janine de Wit

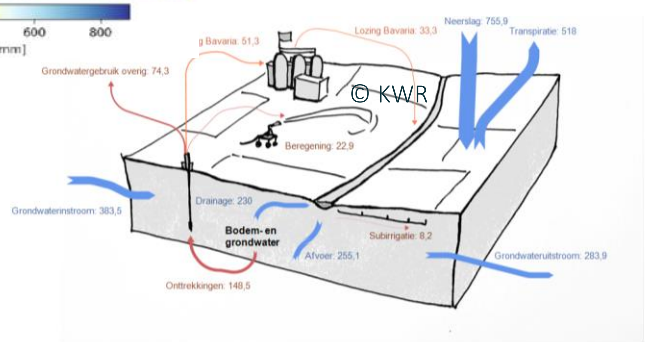


Figure by Esther Brakkee

- Optimizing subirrigation (use less water while crop conditions are optimal)
- Proper management (technical + environment)
- Subirrigation on regional scale

(WEAP/ VenSim)

Work in progress: Water system thinking and modelling

Propagation, benefits and risks of measures

- Water quantity – water quality – stakeholders – governance – policy
- Think integrated: the whole water system needs to be considered

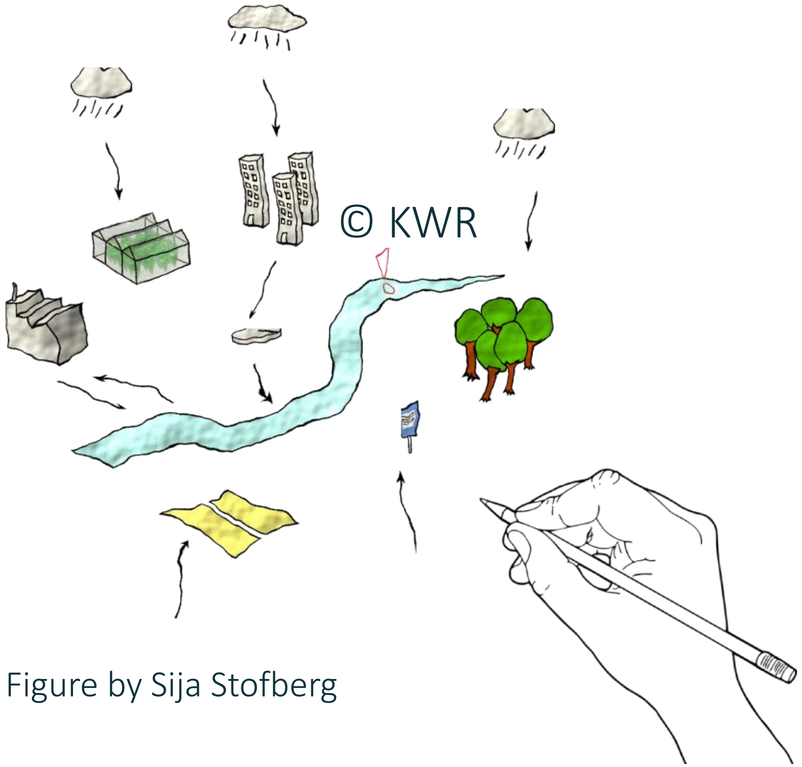
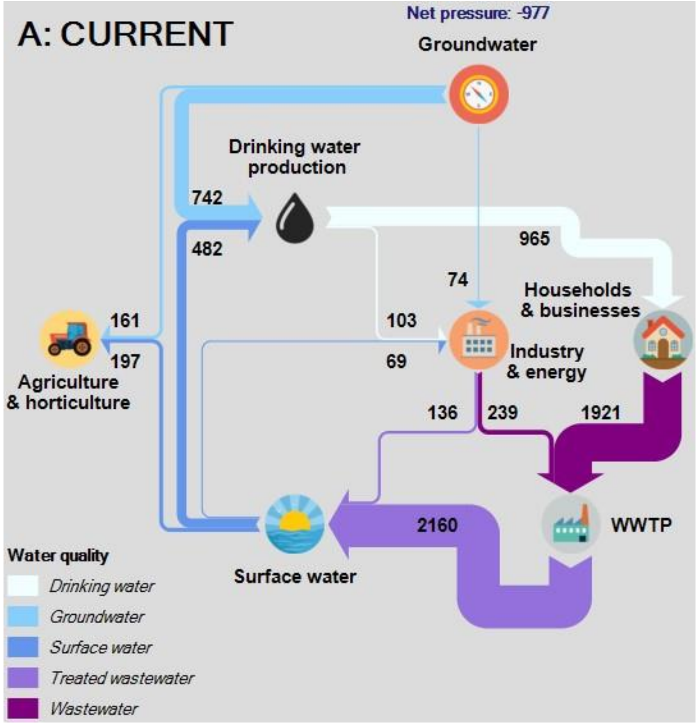


Figure by Sija Stofberg



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Take home message

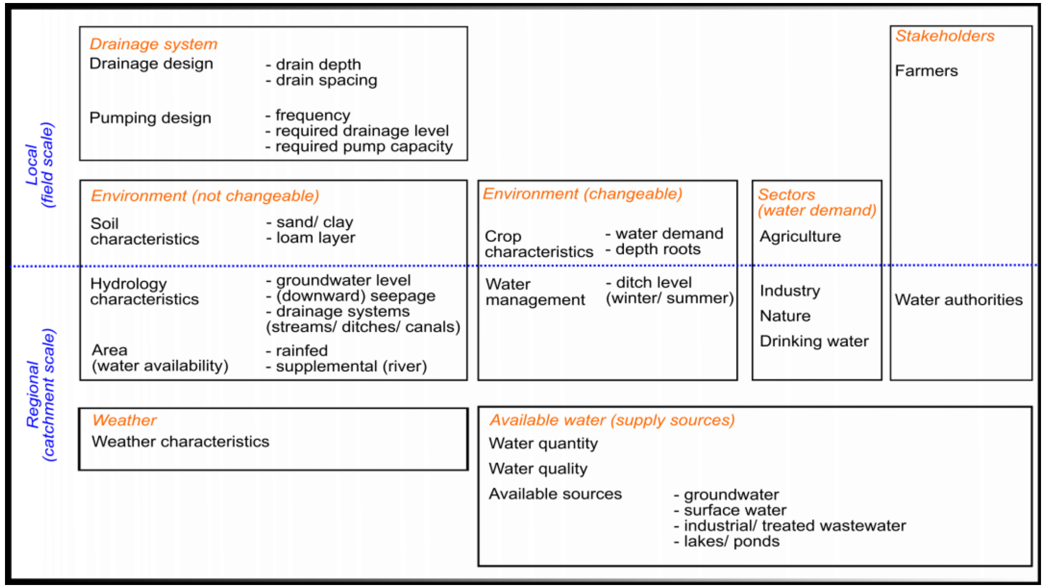
Goal & operational management controlled drainage with subirrigation

- Goal
  - Local scale: raise the groundwater level and increase soil moisture availability for crops.
  - Regional scale: reduce peak discharges, discharge less water, and increase groundwater recharge.

- Operational management (by farmer)
  - Training, capacity building, evaluation, etc..

! Think integrated:

The whole water system needs to be considered !



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