Semi-or fully automatic drainage regulation as a mean to recharge groundwater

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Smart Drainage concept

Climatic change is decreasing water availability, all over the world. Regions which never faced water scarcity need to adapt their practises to face more frequent and severe droughts periods. Among others, agriculture is one of the sectors that will face the consequences of water scarcity. Indeed, while water availability decreases, the use of water for irrigation purposes becomes questionable. In many regions in Europe, cultivated areas have a sub-surface drainage system, which ensures that crops do not face water stress due to excessive soil water content. These drainage systems convey the water infiltrating during rainfall events to surface channels, reducing the natural water percolation. Introducing drainage regulations units in existing drainage systems represent a mean to increase the soil water retention and, consequently, **a mean to increase the natural water table recharge** while decreasing the need of irrigation.

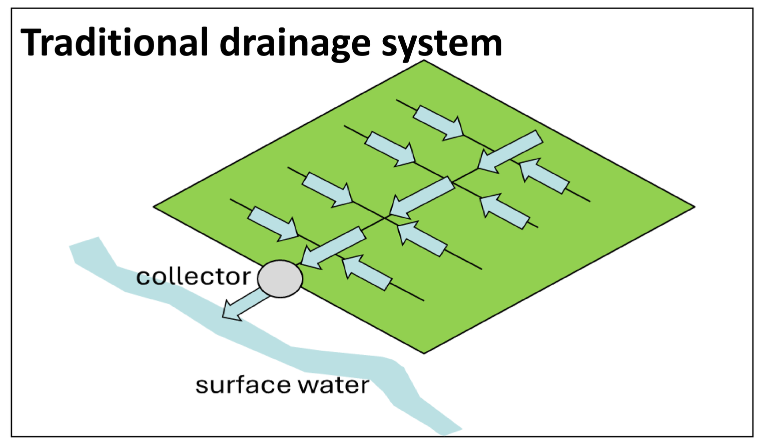

Figure 1: Traditional drainage system → immediate drainage to surface waters → no water storage

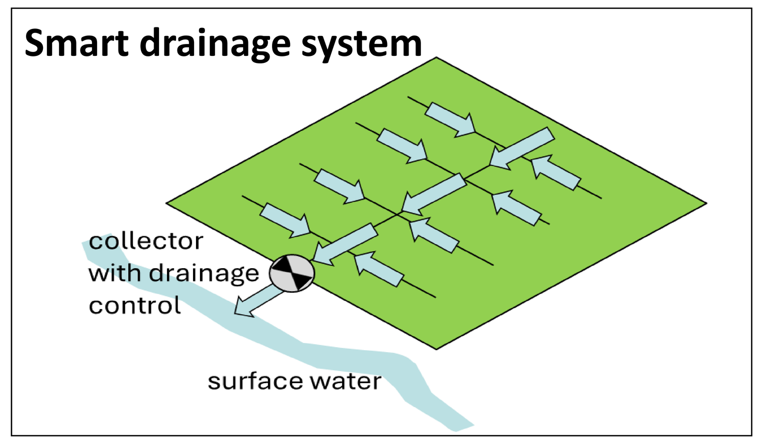

Figure 2: Smart drainage system → controlled drainage to surface water → water storage

Drainage control units can be simple structures retrofitted in existing drainage networks outlets. They can consist of a flashboard with adjustable height, sliding weir systems or floating valves which can be operated manually or automatically.

Controlled drainage systems have several benefits:

- reducing the amount of Nitrogen and Plant Protection Products (PPP) discharged to surface waters (Cooke, Sands, and Brown 2008) (Bonaiti and Borin 2010) (Liu et al. 2019)
- increasing the natural recharge of the water table
- smoothing the peak flow during intense rainfall events
- decreasing the need of irrigation
- increasing crops yield (Poole et al. 2013)

Given these benefits, drainage water control is today an official soil conservation practice in the USA and the Conservation Practice Standard 554 has been published by the US Department of Agriculture to inform and advise potential users. On the contrary, although suitable for any drained field with flat topography and a slope of less than 1%, this practice is not widespread in Europe (except for The Netherlands).

Objectives:

The goal of this study was to develop an automatic drainage system aiming at:

1. understanding the technical and practical difficulties associated with the use of a drainage control unit
2. assesing its effects on the sedimentation of the drainage system
3. gaining insights about its operation in silty soils (very common in the north-west of Switzerland)
4. arising awarness of this practise

Methods

A physical model of a drainage pipe entering in a manhole was built in the laboratory of the Fachhochschule Nordwestschweiz, in scale 1:1. The experimental set up is shown in Figure 3. The pipe drains a terrain having a surface of 5 m^2 and a depth of 1 m, placed in a permeable "cage" made of a rigid plastic net and sustained by a wood structure. The compartments in between the permeable cage and the outer wood walls were filled with gravel and were used to control the water level on its sides, simulating the water table height.

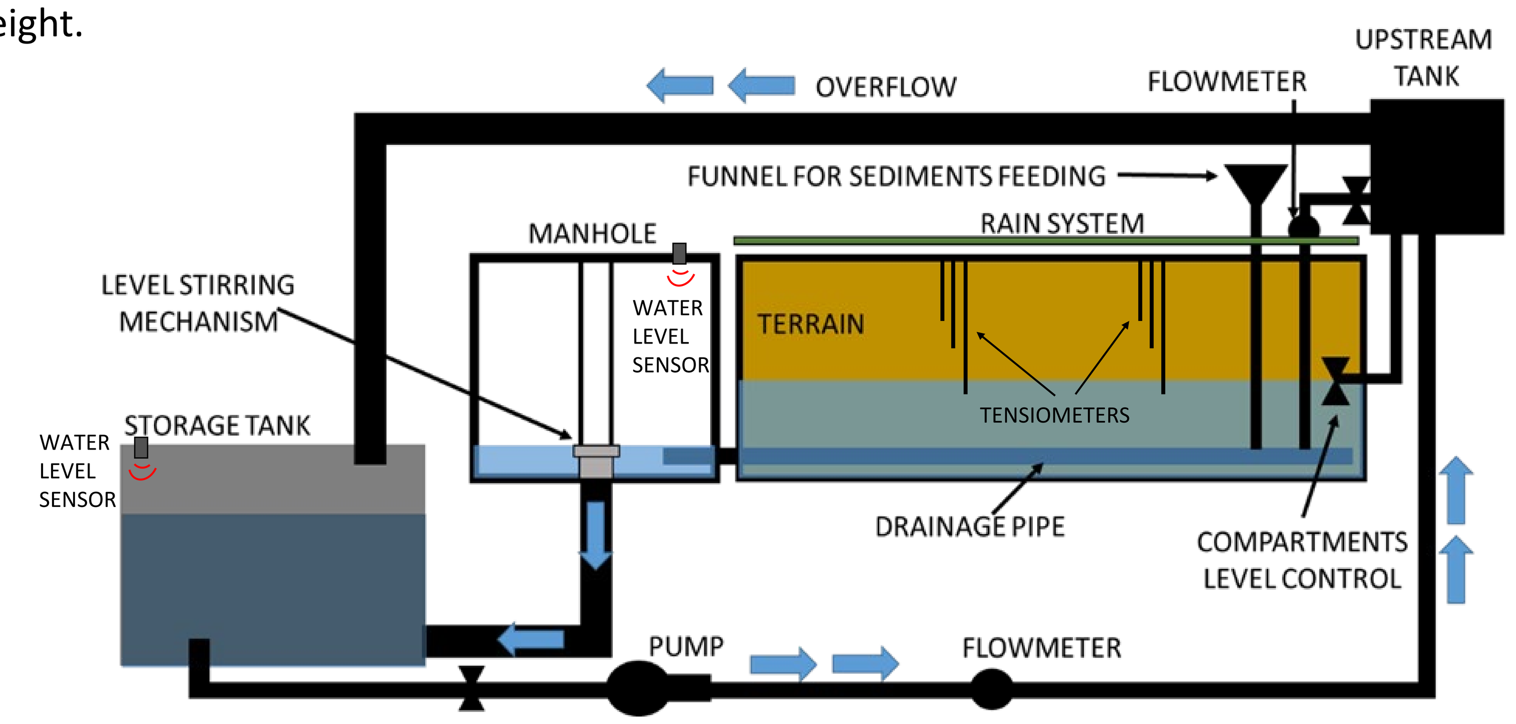

Figure 3: Scheme of the experimental set-up

The pipe drianed the water to a manhole with square cross-section of area 1 m^2. A circular hole in its center, allowed the water to be discharged out and be advected into the storage tank, from where it was pumped back to an upstream tank first and then to the drainage pipe. A valve allowed regulating the discharge of the drainage pipe, while an overflow system ensured a constant water head in the upper tank, conveying the extra water back to the tank.

A funnel, at the upstream end of the drainage pipe, allowed feeding it with the desired quantity of sediments.

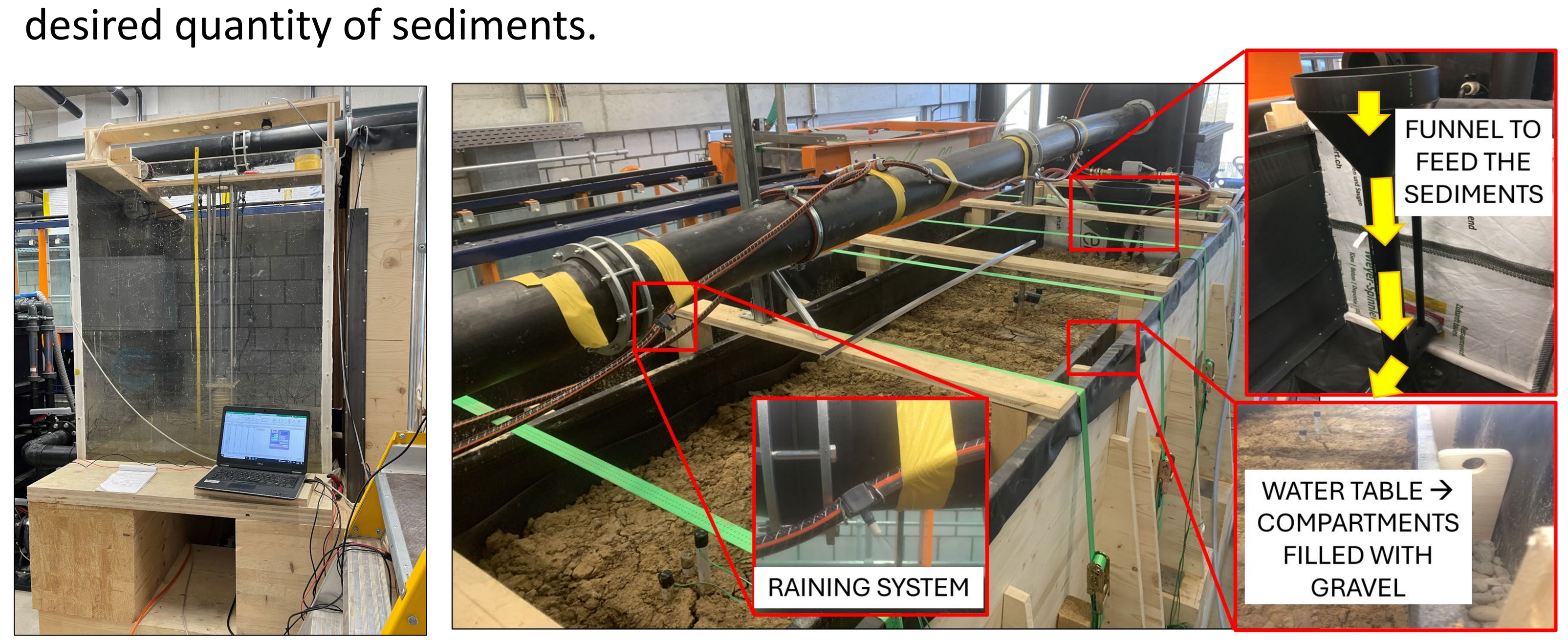

Figure 4: On the left the manhole and on the right the model in the FHNW laboratory

Results

Level stirring meachanism

The level stirring meachanism was assembled using:

- a circular crest weir welded on a stainless steel perforated plate sliding on 4 rails
- an accordion pvc hose (covering a steel spiral), fixed on the stainless plate
- a rigid perforated PVC pipe

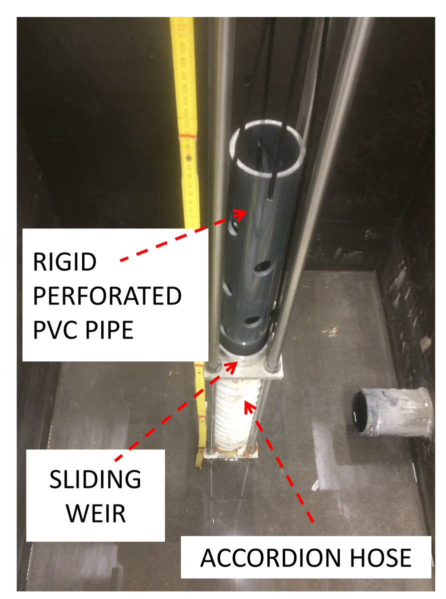

Figure 5: Level stirring mechanism

Manual drainage operation

The drainage control was initially operated manually lifting and lowering the sliding weir with a wire.

Automatic drainage operation

The drainage control was then automized using a motor suitable for electric-bikes and a trasmission chain, transfering the motor rotation to a cylinder. The latter rotation rolled up or unrolled a wire lifting or lowering the weir height.

The motor rotation was controlled through an Arduino code, uploaded on an Arduino MEGA board.

The weir automatic stirring was based on the water level measured in the manhole.

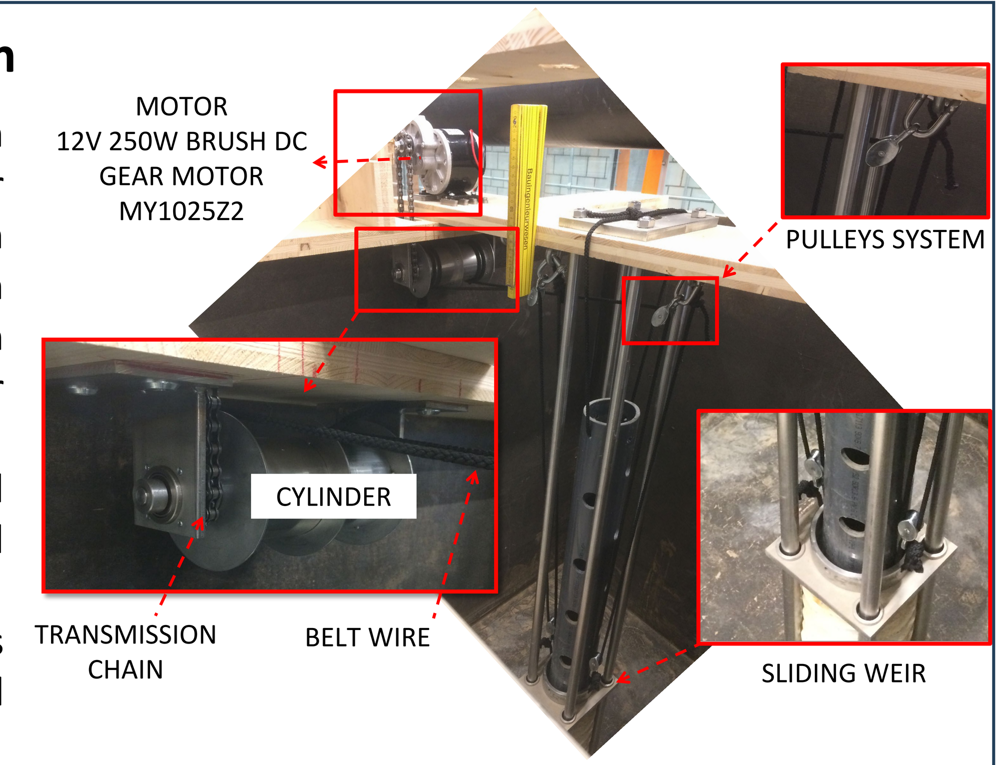

Figure 6: Automatic drainage control mechanism: motor and transmission chain

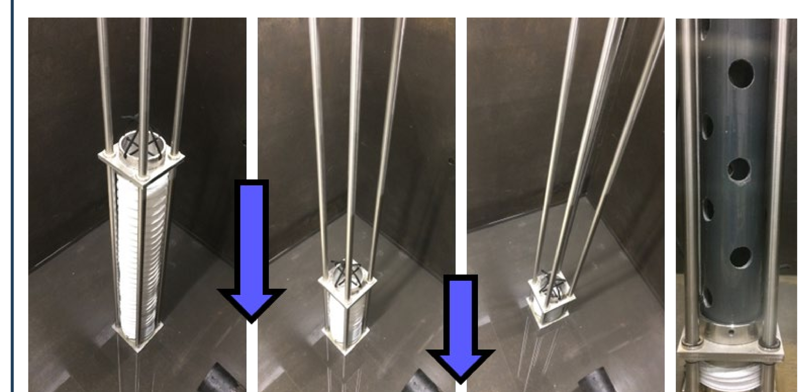

Figure 7: Sequence showing the weir plate, sliding on its rails

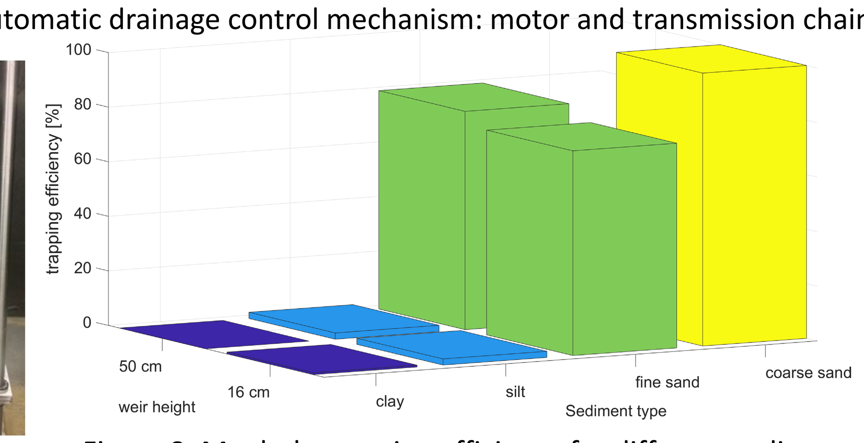

Figure 8: Manhole trapping efficiency for different sediment grains and weir height.

Drainage control effect on sedimentation

As Figure 8 shows, the drainage control improves the retention efficiency of the manhole. On the other hand, it reduces the pipe sediment transport capacity, but it hinders the sediments drying-induced consolidation. For small diameter sediments (i.e. silt, 40% < 0.063 mm), the presence of a drainage control has an almost negligible influence.

Insights about operating drainage control

Drainage control might be more difficult to operate for terrains having slower reaction time (i.e., silty-clay soils). In this case the level control must be operated well in advance (even several days), and thus must be based on accurate weather forecast

Conclusions

An automatic drainage control mechanism was developed in a laboratoty drainage prototype. Its automatic stirring was based on the water level into the manhole. It showed to have pro and cons for what concerns the drainage pipe clogging: it reduced the sediment transport-capacity but it hindered the sediments drying-induced consolidation.

Project partners:

- *Amt für Umwelt - Kanton Solothurn*
- *TerrAquat GmbH*
- *Bund der Ingenieure für Wasserwirtschaft, Abfallwirtschaft und Kulturbau (BWK)*

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