WATERAGRI

D5.2: WATERAGRI Solution Test Findings

M24/April 2022

WP5 Case studies

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WATERAGRI Consortium			
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4	TEKNOLOGIAN TUTKIMUSKESKUS VTT Oy	VTT	FI
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1 Introduction

After Deliverable D5.1 "Description of Case Study Sites", Deliverable D5.2 "WATERAGRI Solution Test Findings" is the second deliverable in WP5 "Demonstration Case Studies". In Deliverable D5.1, each case study site (Figure 1) was described and a first version of the installation plan (i.e. plan for installation for the WATERAGRI solutions at the case study site) and of the research plan have been developed for each site.

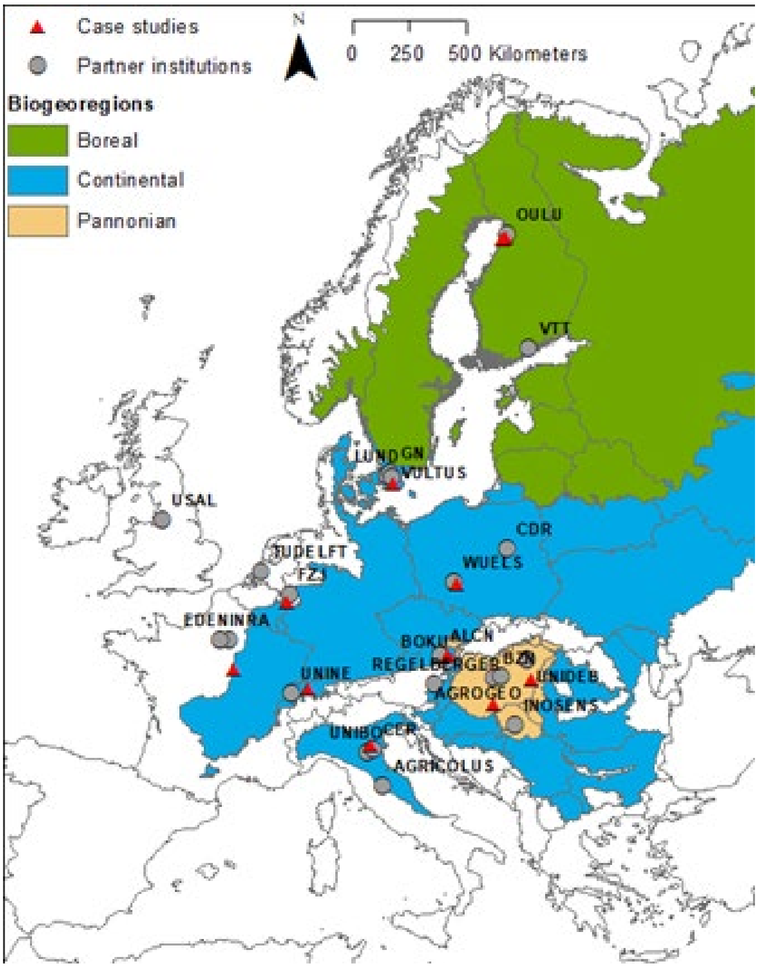


Figure 1: Location of WATERAGRI case studies (red triangles).

Deliverable D5.2 is linked to Milestone MS11 "WATERAGRI Solutions Implemented". The document thus provides information on the WATERAGRI solutions implemented at the case study sites.

2 Methodology

In Deliverable D5.1, for each case study site, the following information was provided:

- The general description of the site (including climate, land use, soil/s, farming, drainage and irrigation practises, etc.)
- The WATERAGRI solutions at the site and the partners involved
- The data availability
- The implementation and research plan

In Deliverable D5.2, we report in the implementation of the WATERAGRI solutions that are implemented at the case study sites, i.e., for each case study site, the following information is provided:

- A short general description of the site including the WATERAGRI solutions at the site,
- The updated implementation and research plan,
- Updated information on data availability and data provision, and
- A photo documentation on implemented WATERAGRI solutions

3 Case study description

3.1 Overview

Table 1 shows the overview of the 10 WATERAGRI case study sites including the updated list of main contact persons and their email addresses.

Table 1: Overview on WATERAGRI case study sites and updated main contacts (new contacts shown in blue colour).

	Site	Partner	Main contact	Email
	Boreal zone			
1	Finland I – Municipality of Tyrnävä	OULU	Björn Klöve Ali Torabi Haghigh Kedar Ghag Syed Mustafa	bjorn.klove@oulu.fi Ali.TorabiHaghighi@oulu.fi Kedar.Ghag@oulu.fi Syed.Mustafa@oulu.fi
2	Finland II – Municipality of Ruukki	OULU	Hannu Marttila	hannu.marttila@oulu.fi
	Continental zone			
3	Sweden – Gårdstånga Nygård	GN ULUND	Gustaf Ramel Suhad Almuktar	gustaf.ramel@gardstanga.se suhad.almuktar@tvrl.lth.se
4	France – Auxerre	INRA	Raymond Reau Laurette Paravano	raymond.reau@inrae.fr l.paravano@yonne.chambagri.fr
5	Germany – Selhausen	FZJ	Harrie-Jan Hendricks Franssen Richard Hoffmann	h.hendricks-franssen@fz-juelich.de r.hoffmann@fz-juelich.de
6	Poland – Lower Silesia	UPWr	Wieslaw Fialkiewicz	wieslaw.fialkiewicz@upwr.edu.pl
7	Switzerland – Seeland	UNINE	Philip Brunner Oliver Schilling	philip.brunner@unine.ch oliver.schilling@unine.ch
8a	Austria –Obersiebenbrunn	BOKU	Christine Stumpp	christine.stumpp@boku.ac.at
8b	Austria – Mistelbach	BOKU ALCN	Christine Stumpp Eriona Canga	christine.stumpp@boku.ac.at eriona.canga@alchemia-nova.net
8c	Austria –Gleisdorf	TBR ALCN	Martin Regelsberger Eriona Canga	martin@regelsberger.at eriona.canga@alchemia-nova.net
9	Italy – Bologna	UNIBO and CER	Attilio Toscano Stevo Lavrnic Francesco Cavazza Stefano Anconelli	attilio.toscano@unibo.it stevo.lavrnic@unibo.it cavazza@consorziocer.it anconelli@consorziocer.it
	Pannonian zone			
10	Hungary – Nyírbátor	UNIDEB	Attila Nagy	attilanagy@agr.unideb.hu

Table 2 shows the overview of the WATERAGRI solutions including the updated list of main contact persons and their email addresses. The WATERAGRI solutions are grouped into 3 groups:

1. Framework Modelling
2. Innovative and Sustainable Water Retention Solutions
3. Nutrient Recovery Solutions

Table 2: Overview on WATERAGRI solutions and updated main contacts (new contacts shown in blue colour).

Framework Modelling (Group A):	**Main contact**	**Email**
Framework (**A1**; UNINE)	Philip Brunner	philip.brunner@unine.ch
Integrated physically-based terrestrial system models (**A2**; FZJ);	Harrie-Jan Hendricks Franssen	h.hendricks-franssen@fz-juelich.de
Decision support system (**A3**; AGRICOLUS)	Diego Guidotti	d.guidotti@agricolus.com
Water-vapour sorption isotherm and water retention characteristics model (**A4**; USAL)	Yu Wang	y.wang@salford.ac.uk
WebGIS for zoning landscape matrix (**A5**; AGRICOLUS);	Diego Guidotti	d.guidotti@agricolus.com
Serious gaming (**A6**; TUDELFT)	Aashna Mittal	A.Mittal@tudelft.nl
Innovative and Sustainable Water Retention Solutions (Group B)	**Main contact**	**Email**
Farm constructed wetlands for water retention (B1; ULUND);	Suhad Almuktar	suhad.almuktar@tvrl.lth.se
Remote sensing pipeline (B2; VULTUS);	Haidi Abdullah	haidi.abdullah@vultus.se
Irrigation management and agrometeorological monitoring solutions (B3; AGRICOLUS);	Diego Guidotti	d.guidotti@agricolus.com
Precision irrigation system (B4; AGRICOLUS);	Diego Guidotti	d.guidotti@agricolus.com
Enhanced water retainer product and concept (B5; BZN);	Nora Hatvani	nora.hatvani@bayzoltan.hu
Biochar for water retention (B6; ALCN),	Eriona Canga	eriona.canga@alchemia-nova.net
Tracer methods (B7; BOKU);	Christine Stumpp	christine.stumpp@boku.ac.at
Dewaterability estimation test apparatus (B8; USAL)	Yu Wang	y.wang@salford.ac.uk
Nutrient Recovery Solutions (Group C)	**Main contact**	**Email**
Farm constructed wetlands for nutrient recovery (**C1**; ULUND),	Suhad Almuktar	suhad.almuktar@tvrl.lth.se
Drainage systems (**C2**; ALCN),	Eriona Canga	eriona.canga@alchemia-nova.net
Bio-based nutrient-collecting membranes (**C3**; VTT),	Mona Arnold	Mona.Arnold@vtt.fi
Biochar adsorbents for nutrient uptake (**C4**; ALCN);	Eriona Canga	eriona.canga@alchemia-nova.net
Microfluidics (**C5**; EDEN).	Cécile Perrault	cecile.perrault@eden-microfluidics.com

3.2 Case study 1 - Municipality of Tyrnävä (Finland 1)

3.2.1 General overview

Table 3: General overview – Case study 1

Case study	WATERAGRI solutions	Partner involved
Finland I 	Physical modelling (HydroGeoSphere) (A2) Remote sensing pipeline (B2) Irrigation scheduling (B3) Bio-membranes (C3),	Leader: OULU Participants: UNINE, FZJ, VTT and OULU

3.2.2 Updated implementation and research plans

Table 4: Updated implementation plan – Case study 1

Original plan (M9, January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
The site has been run as a pilot in 2018. We aim to repeat and develop measurements for the period 2021-2023.	The historical records required for the investigation has been collected, analysed, and preliminary results were obtained. Further detailed scenario-based analysis using extended data is ongoing. The measurements for 2021-2023 have started. 2 groundwater level monitoring sensors, 4 soil moisture sensors, and 2 air temperature and humidity sensors were installed in 2021 after discussion with the farmer. Data for cropping seasons 2018, 2019, 2020, and 2021 were collected, and analysis is ongoing.

Table 5: Updated research plan – Case study 1

Original plan (M9, January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
Depending on farmers, we plan to install sensors in 2021. We will also analyse data form 2018 and data collected with remote sensing. Key stakeholders are farmers, municipalities and the regional EPA (ELY centre in Oulu)	A meeting with the farmer who owns the land was carried out during the first field visit before the beginning of cropping season 2021. As mentioned above in the implementation plan, 8 hydrometeorological sensors were installed after discussion with the farmer. The part of hydrometeorological data measured in 2018,

	2019, and 2020 was collected and analysed. The remaining data analysis is ongoing, along with new data collected during cropping season 2021. Several RS data were collected, and analysis was carried out. We plan to install 4 more groundwater level monitoring sensors around the field. Other necessary information to get the preliminary understanding of the field and the region were collected from the farmer, Natural Resources Institute Finland (LUKE) and the Regional Centre for Economic Development, Transport and the Environment (ELY Centre in Oulu). We continue our research on real-time irrigation scheduling, the effectiveness of CD management, and reuse & improved use of drainage water for irrigation through improved drainage control.

3.2.3 Data availability and data provision

Table 6: Data availability – Case study 1

Original plan (January 2021, i.e., D5.1)	**Updated plan (M24, April 2022)**
1) Availability of data	
Data on soil and moisture available for one season in 2018. New measurements planned after discussion with landowners.	Following data are measured and are available on request: • Frequent: crop yield (per ha) of Tyrnävä, crop cultivated area under Tyrnävä In-situ Monitoring 2018, 2019, and 2021: • Continuous: Soil moisture and groundwater levels Weather Monitoring 2018-2021: • Continuous: Precipitation, Air temperature, Wind speed, Humidity, Soil temperature, Light intensity, Solar radiation, Air pressure etc.) RS data: • Land Use Land Cover (Sentinel 1-2) • Precipitation (GPM and TERRA Climate Model)

	• Land Surface Temperature, LST (MODIS) • Reference Evapotranspiration, ET (MODIS) • NDVI (LANDSAT) Additionally, the following data are collected and are available on request. • DEM (2×2m) • Land use land cover (LULC) • Soil types
2) Data that are planned to be measured	
Soil moisture, water table and ditch water level	Following data are planned to be measured: In-situ monitoring during crop season 2022: • Weather monitoring during crop season 2022 • Continuous: groundwater level, Precipitation, Air temperature, Wind speed, Humidity, Soil temperature, Light intensity, Solar radiation, Air pressure etc. Frequent: Ditch water level.

Table 7: Current status of data provided – Case study 1

Which data have been made available to be included in the database until date?	Following data have been provided to include in the database of AGIRCOLUS until the end of December 2021: • georeferenced shapefile of the case study area • crop details for the field • DEM (2×2m) • soil types map • bed rock maps for the study area Following data are available to be included in the database on request until the end of September 2022: • Frequent: crop yield (per ha), crop cultivated area • Monitoring 2019 and 2021: • Continuous: Soil moisture and groundwater levels, weather data (i.e., Precipitation, Air temperature, etc.) Weather Monitoring 2018-2021: Continuous: Precipitation, Air temperature, Wind speed, Humidity, Soil temperature, Light intensity, Solar radiation, Air pressure etc.
Which data will be available to be included in the database within this year? (e.g., until end of September 2022)	Following data will be available within the next year (e.g., until the end of April 2023): In-situ Monitoring 2022: • Continuous: groundwater levels, River discharge of Tyrnävä sub-catchment Weather Monitoring 2022: • Continuous: Precipitation, Air temperature, Wind speed, Humidity, Soil temperature, Light intensity, Solar radiation, Air pressure etc. • Frequent: Ditch water level. Different water balance components simulated using HGS

3.2.4 Photo documentation

In the Tyrnävä case study area, the following WATERAGRI solutions are implemented and work in progress:

1. Irrigation scheduling (B3)
2. Remote sensing pipeline (B2)
3. Physical modelling (HydroGeoSphere) (A2)

Whereas the following WATERAGRI solution is planned to be implemented during the crop growing season in 2022:

1. Bio-membranes (C3)
   We will provide water samples to VTT to evaluate the effectiveness of the membranes (C3; VTT) solution in reducing the nutrient loading to surface water from the agricultural field.

In this section, we give photo documentation on implemented and ongoing work in the Tyrnävä case study area.

3.2.4.1 Preparations before the implementation of the WATERAGRI solutions

A field visit was carried out at the beginning of the cropping season in 2021 to understand the different aspects of agricultural water management in the Tyrnävä Field study site (Figure 2). We also explained the site owner about our planned WATERAGRI solutions and how the expected results could help in improving the regional agricultural water management (Figure 3).

Figure 2. Tyrnävä Field study site (Finland1)

Figure 3. A snapshot of the discussion with farmer during the field visit

After that, different instruments to collect hydrometeorological data were installed in the field, as shown in Figure 4. The data collection was started from the start of cropping season 2021. The schematic representation of the water level sensor installed in the drainage wells at the Tyrnävä study field site is shown in Figure 5. It also shows the soil moisture sensors installed in the field at different soil depths.

Figure 4. IoT setup installed at Tyrnävä field study site during the cropping season 2021

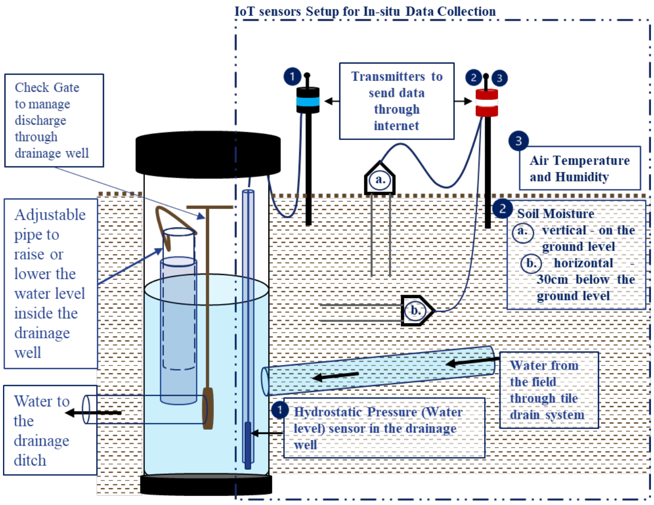


Figure 5. Schematic representation of IoT setup installed in the field for In-situ data collection

The high resolution (temporal) weather parameters (Figure 6) were collected from the automatic weather station of "Holfuy", which has already been installed at the Tyrnävä field study site. Moreover, the requested basic details were uploaded on the AGRICOLUS platform, as shown in Figure 7.

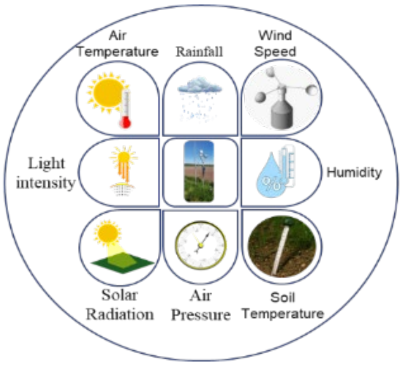


Figure 6. Collected weather parameters from *Holfuy*-Automatic Weather Station (AWS)

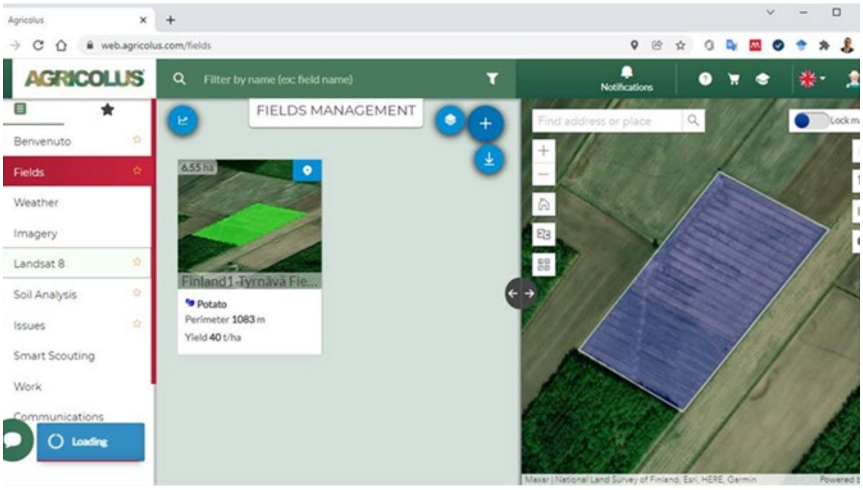


Figure 7. Tyrnävä study field site details created on the AGRICOLUS platform

After that, the WATERAGRI solutions are implemented, and the work is in progress. The test finding is explained in the following sub-section, along with the ongoing and planned work strategies.

3.2.4.2 Water Balance Simulation

We developed a novel Water Balance Simulation (WBS) that is able to quantify irrigation and drainage requirements simultaneously. This WBS will help to understand the crop's water availability and water requirement. Potato crop information, including the planting and harvesting date, were collected from the Natural Resources Institute Finland (LUKE). The details of the WBS and results obtained using WBS have already been reported in deliverables 3.1 and 3.2. However, as part of continuous improvement, we have updated different parameters of our WBS to improve the reliability of the prediction. The updated results based on updated WBS parameters are shown in the following figures (Figures 8 and 9). Figure 8 shows the irrigation requirement observed in the Tyrnävä field from 2000 to 2020. It is observed that irrigation was required only four cropping seasons (2003, 2006, 2018 and 2019) out of 21 cropping seasons (May to September). The highest 120 mm of irrigation requirement was observed in 2006 cropping season. This indicates 2006 was the worst cropping season in terms of water availability. This also confirms the observed minimum rainfall of that cropping season.

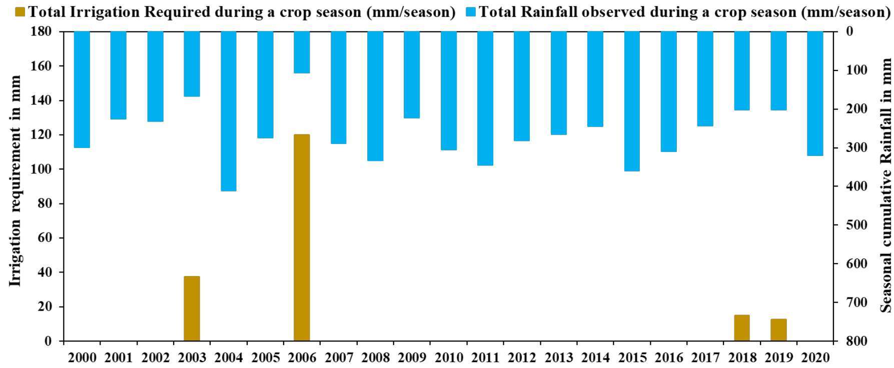


Figure 8. Irrigation requirements observed in the Tyrnävä field from 2000 to 2020

Figure 9 shows the drainage requirement observed in the Tyrnävä field from 2000 to 2020. The result shows that the Tyrnävä field site requires drainage more often than irrigation, which is normal in Finland. The highest 140 mm of drainage requirement was observed in the 2004 cropping season, and this is because rainfall was highest in that cropping season. The cropping season 2006 that showed the highest irrigation requirement, also showed around 30 mm of drainage requirement from the field during the cropping season. It also highlights that the rainfall distribution during the entire cropping season might play an important role, which needs to be investigated more. We also acknowledge that model prediction may vary if we change the cropping window. That's why we are continuously improving the WBS.

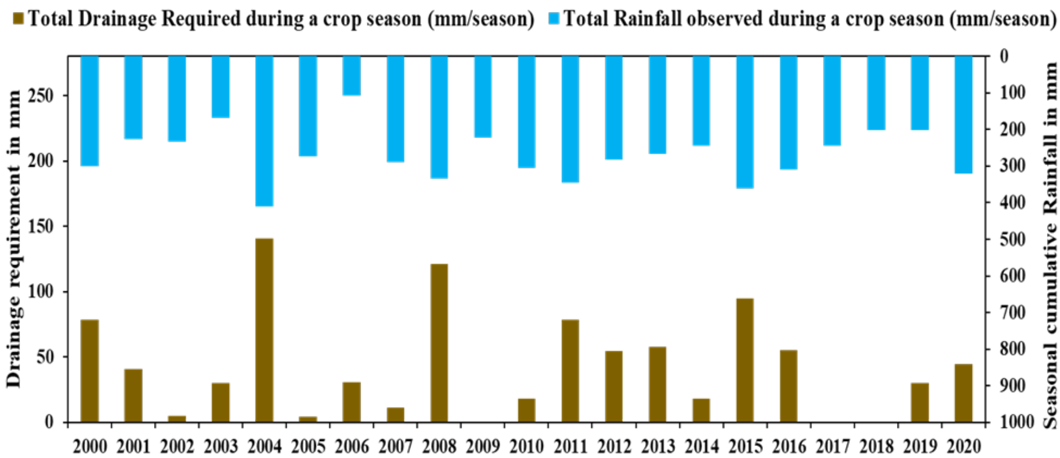


Figure 9. Drainage requirements observed in the Tyrnävä field from 2000 to 2020

3.2.4.3 Multi-module smart drainage management approach

Besides excess water, summer drought is a recurring phenomenon in Nordic agriculture, including our case study area and causes substantial yield losses. Additionally, diffuse nutrient pollution from agriculture, mainly due to poorly managed subsurface drainage systems, is a primary concern for the ecological health of European river basins. The reuse and improved use of drainage water for fertigation through improved drainage control could be an essential strategy to reduce yield losses during summer drought and nutrient loading to surface water. We present a simple, flexible, and eco-friendly approach to reusing drainage water for fertigation through improved drainage control and promoting a circular economy in challenging Nordic conditions. This also joins the European Union (EU)'s effort to accelerate the transition towards the circular economy to achieve the Sustainable Development Goals (SDGs).

Multi-module smart drainage management approach

Our proposed simple, smart drainage management approach to reuse drainage water for fertigation through improved drainage control for overcoming summer drought consists of three modules (Figure 10): (i) meteorological forecasting, (ii) hydrological simulation, and (iii) the practical implementation of irrigation and drainage control using novel ICT-based sensor network solutions. The implementation module has two parts: an automatic drainage control regulating the amount of agricultural field water and the reuse of drainage water for fertigation feeding back automatically into the drainage system.

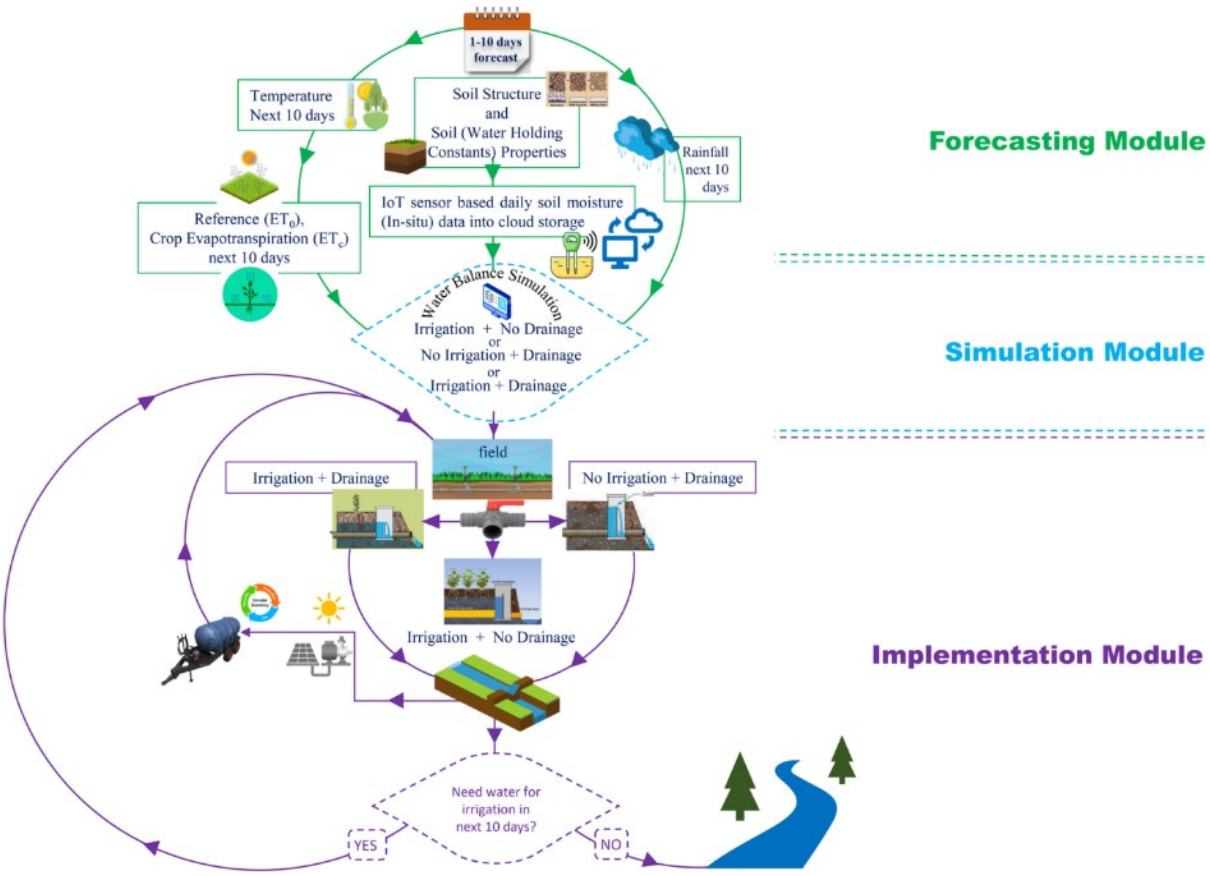


Figure 10: The proposed multi-module smart drainage management approach.

Meteorological Forecasting Module

In the first module, the forecasted hydro-climatological data of the study area are collected and characterized in detail. The 1-10 day forecasted rainfall and temperature data, provided by regional authorities and meteorological institutes, are used as initial input. The forecasted temperature is applied to estimate the daily reference evapotranspiration (ET0). The crop evapotranspiration (ETc) will be calculated based on the ET0 and crop coefficient (Kc) in the different growth stages.

Hydrological Simulation Module

Using ETc, current soil water holding, and forecasted rainfall, the daily soil moisture will be estimated for the next 10 days using the Water Balance Simulation (WBS) in the hydrological simulation module. We can also estimate soil moisture for the next 10 days using FAO crop water productivity model, AquaCrop (Raes et al., 2009a). The results of the WBS or AquaCrop will propose tentative irrigation or drainage demand values to farmers (or system operators). This provides the basis to implement optimal irrigation or drainage management.

Implementation Module using novel ICT based sensor network

In the first step of the implementation module, the water level in the crop field will be optimized by using the automatic drainage control system. For instance, if currently (e.g., today) the field has enough water, but no (or deficit) rainfall is forecasted within the next 10 days, the drainage valve will automatically be closed (or partially closed) to keep soil moisture near the root zone. Conversely, if an extreme rainfall event is forecasted, a drainage valve will automatically be fully opened to facilitate drainage and avoid waterlogging. WBS simulation takes advantage of the ICT sensors by considering soil hydraulic properties (e.g., soil water retention curve) to regulate the drainage outflow.

In the final part of the implementation module, the excess drained water from heavy rainfall events can be stored in a buffer pond or portable storage tank (Figure 10). Some parts of the drainage ditch, beside the field, can be used as a buffer pond by applying a water level controller. During a summer drought, the stored water can be used for fertigation. Care needs to be taken in assessing the water quality of the stored water, thus avoiding excess fertilization and degradation of soils (i.e., through heavy metals, salinization, etc.). The assessed irrigation water can be fed back through the existing drainage system using these as underground irrigation pipes, thus avoiding additional irrigation infrastructure and using emission-free systems (e.g., solar pumps). An elevated storage tank can also help overcome the possible uncertainty in the weather predictions. A solar pump will be applied to store drained water into a portable storage tank which can then be used for fertigation by gravity flow. Given the climatic conditions of the Nordic region, the tank can be filled with melted water from snow before the cropping season. Additionally, the drainage water recycling reduces nutrient loading to surface water from agriculture.

A hypothetical experiment

A hypothetical experiment was conducted to evaluate our proposed smart drainage management approach to reusing drainage water for irrigation through improved drainage control. For that FAO crop water productivity model, AquaCrop (Raes et al., 2009a) has been used. AquaCrop needs climatic data (rainfall, temperature and reference evapotranspiration), soil data (physical characteristics) and crop data (conservative and non-conservative parameters) as model inputs. Time series of daily rainfall and temperature collected from FMI were used for model development and calibration. The reference evapotranspiration (ET_0) was calculated based on the FAO Penman-Monteith equation (Allen et al., 1998) using FAO- ET_0 calculator. Soil physical characteristics were defined using the field site data, and water retention curves were developed based on observed data. Crop non-conservative parameters were defined based on the Potato crop of our field in Tyrnävä, whereas conservative parameters for Potato were adopted from the AquaCrop manual for Potato. Finally, model performance was evaluated using the observed dry tuber yield of Tyrnävä from 1999 to 2020. Figure 11 shows the observed and simulated dry tuber yield. It is observed that the model is slightly overestimating the dry tuber yield of potatoes. However, the yearly variation of dry tuber yield of potatoes is very well simulated by the model (Figure 12). This indicates the acceptable simulation capacity of the AquaCrop model.

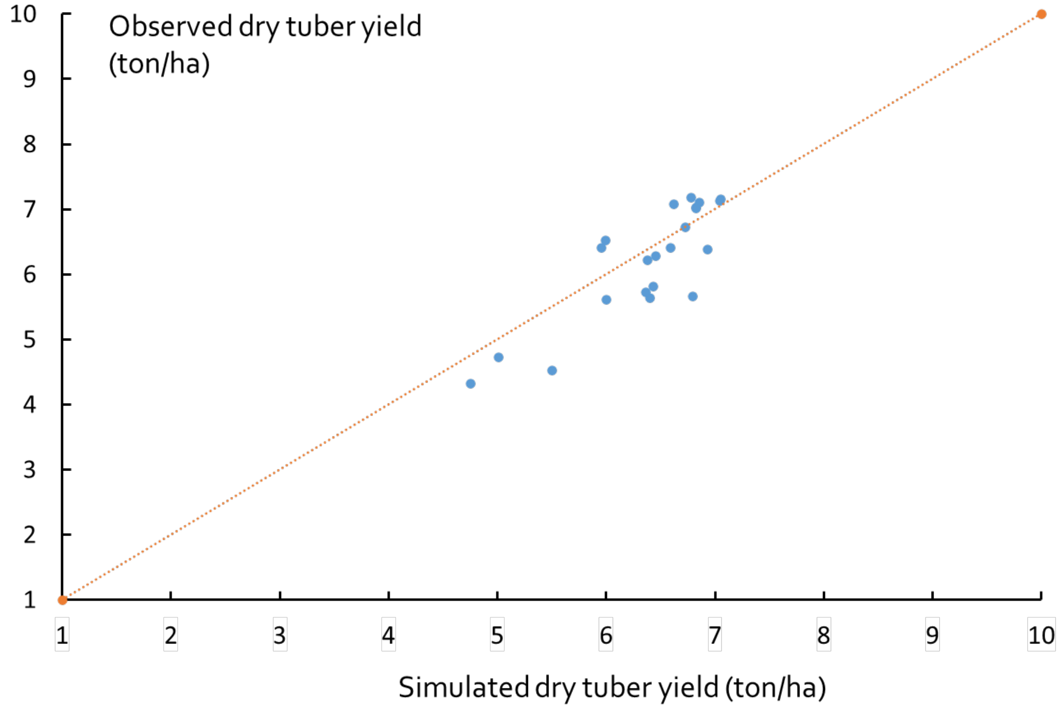


Figure 11: 1:1 plot comparing observed and simulated dry tuber yield of potato.

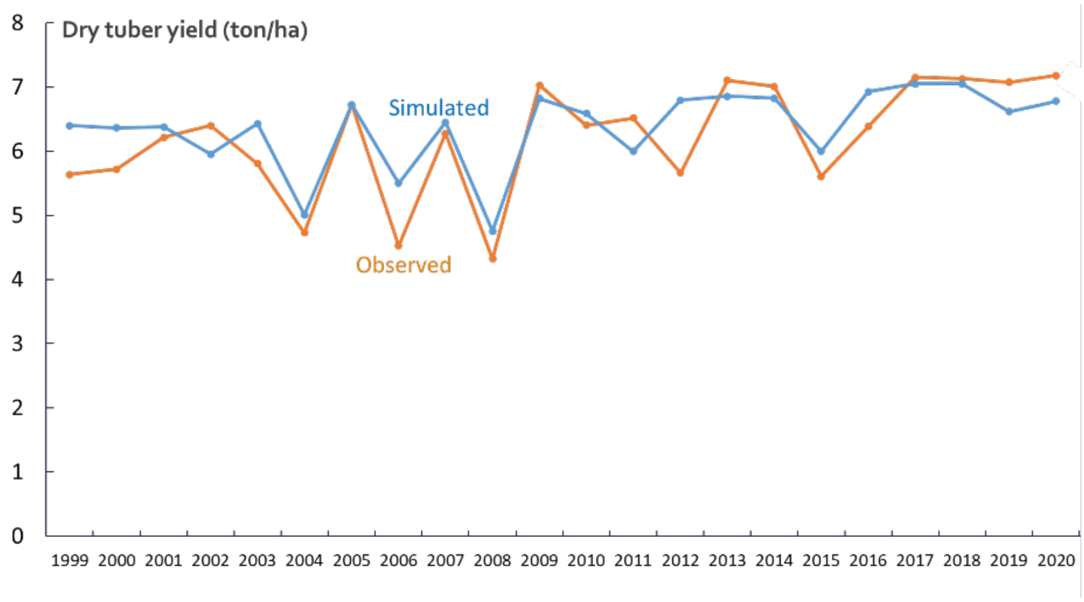


Figure 12: Comparison of observed and simulated dry tuber yield of potato from 1999 to 2020.

Currently, there are no irrigation facilities in the field. So, both observed and simulated dry tuber yield of potato is under rainfed conditions. It is observed that under the rainfed condition, there were significant yield losses in 2004, 2006, 2008, 2012 and 2015.

Then dry tuber yield of Potato was simulated considering irrigation keeping all other parameters exactly the same as the rainfed simulation (Figure 13). The irrigation requirement was calculated considering the allowable depletion of 30 % of Readily available water (RAW). This also helps us to avoid the waterlogging situation in the field. The results show that yield losses in 2004, 2006, 2008, 2012 and 2015 can be reduced by providing minimal irrigation during dry seasons. The irrigation requirement was minimal, and this small amount of water can easily be provided by reusing drainage water for irrigation through improved drainage control. We are aware of the model prediction uncertainty, and that’s why our efforts continue in improving the reliability of the model prediction.

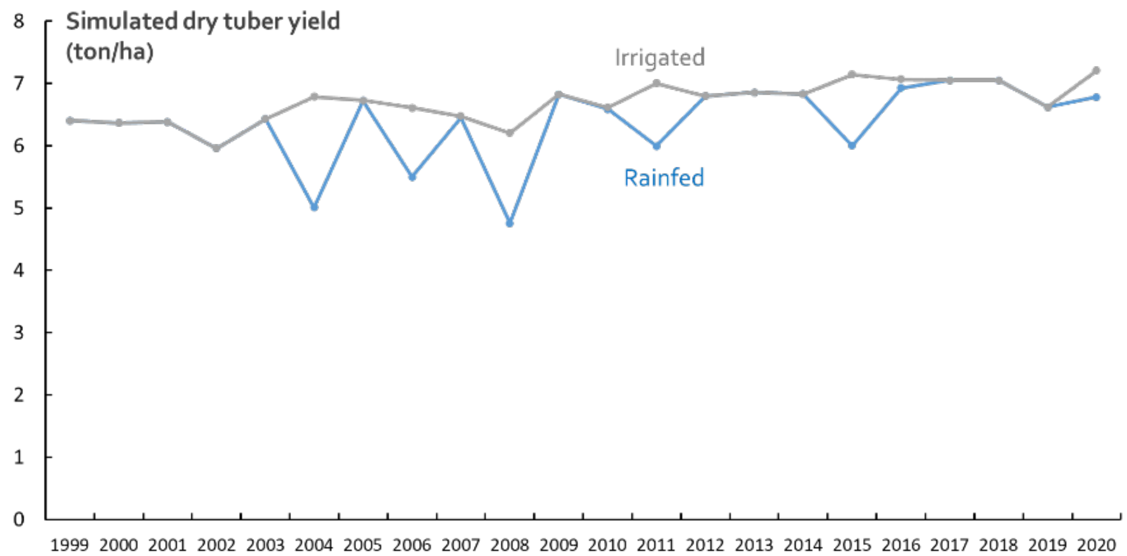


Figure 13: Simulated dry tuber yield of potato under rainfed (blue) and irrigated (grey) conditions from 1999 to 2020.

3.2.4.4 Impact of climate variability on crop yield and water management using remote sensing:

The remote sensing analysis was carried out to investigate the impact of climate variability on crop yield and water management using remote sensing products. The details of the adopted methodology and observed results were documented already in WATERAGRI D3.1. We also proposed an RS data-based climatic Index to assess the sensitivity of crop yield to climate. A manuscript comprising all the details is ready for submission in the journal, and that’s why we didn’t add the details here. However, it will be reported in the project's next deliverable after the manuscript gets published.

3.2.4.5 Numerical modelling

We set up two (one on basin-scale and one on field Scale) integrated surface-subsurface hydrological models using HydroGeosphere (HGS) (Aquanty, 2015). Here we explain more details on the field scale model as D5.2 mainly focuses on the case study area. A field scale model is set up to (i) evaluate different irrigation options during droughts using, for example, stream water and groundwater, and (ii) evaluate the effectiveness of drainage management on WTL control.

Model setup

The available hydrogeological data of the Tyrnävä field are characterized in detail. The hydrogeological parameters of the model are identified based on existing data and their spatial, temporal, and vertical variability. The Isosuo potato field area (0.064 km^2) is discretized into an approximately equilateral 2D triangular element mesh with 1808 nodes and 3422 elements for the field-scale model (Figure 14). The element size varies within the mesh, with higher resolution around predefined groundwater wells areas. Then, the mesh is used to develop a 3D 8-layered flow model (Figure 15). The digital elevation model (DEM) is used as the top of the model domain. The bottoms of the top 4 layers were located at 0.15, 0.3, 0.45, and 0.6 m below the ground surface to better represent the flow in the unsaturated medium. A no-flow boundary is considered on every side of the model except for the field outlet. A no-flow boundary is also assumed at the bottom of the model domain as the flow is restricted by the relatively impermeable bedrock. The bedrock surface elevation is used as the bottom of the model domain.

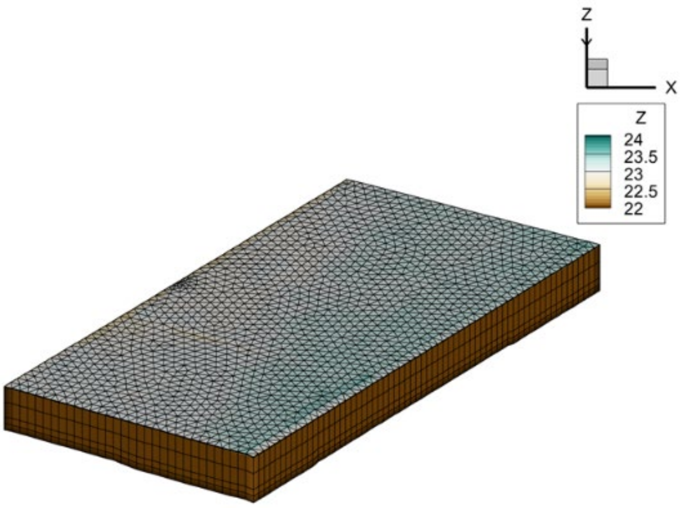


Figure 14: The numerical mesh of the Tyrnävä field model as currently implemented in HGS along with elevation (Z: m).

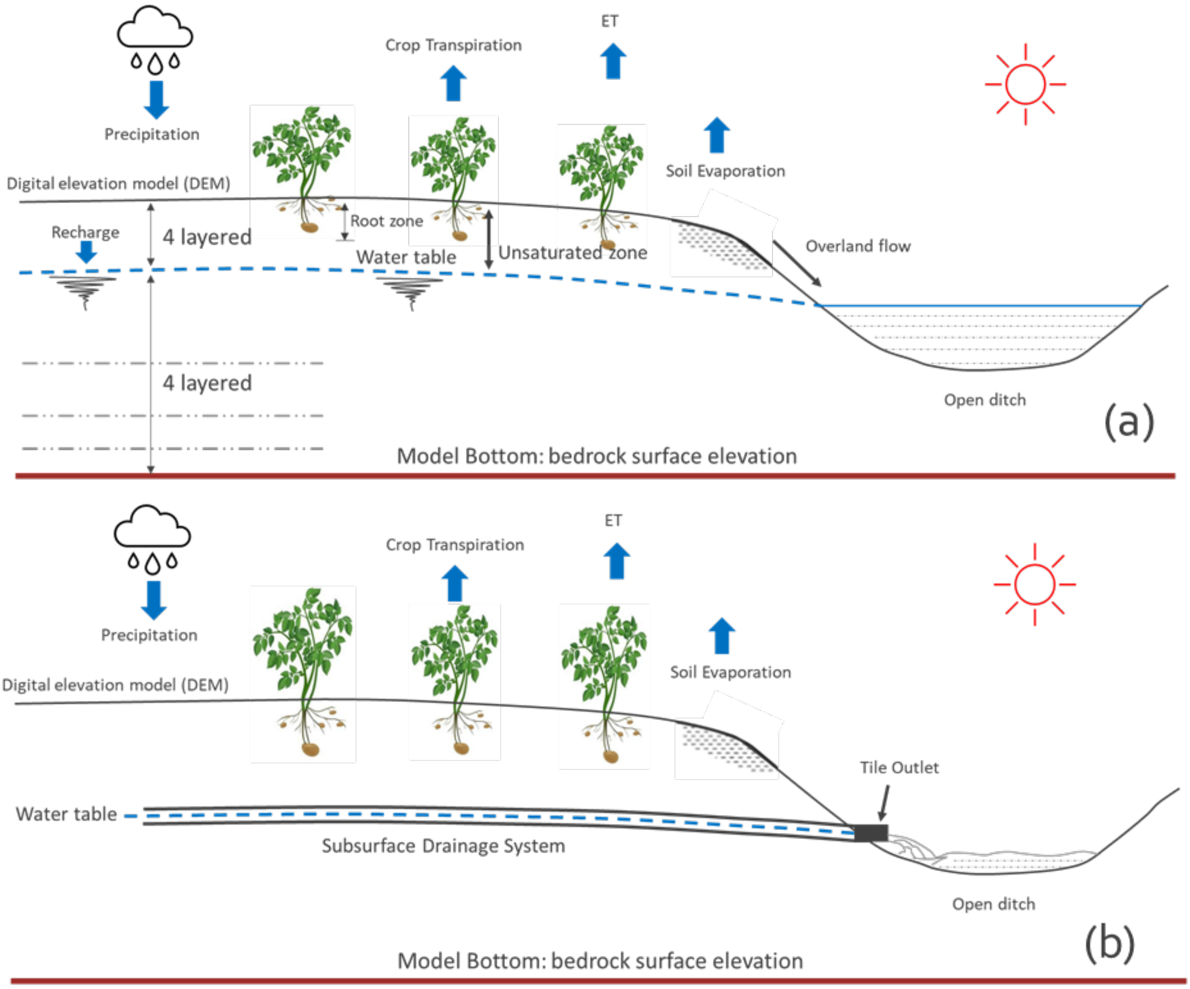


Figure 15: Conceptual model: (a) undrained condition, (b) drained condition.

Conceptual model is developed considering two different scenarios (i) without tile drainage and (ii) with tile drainage (Figure 16). We are considering existing tile drainage in the field for the second scenario. There are two main pipes and 25 lateral drainpipes (Figure 18) with a drain spacing of 15 m, a drainage depth of 1 m, and a tile diameter of 0.1 m in the Tyrnävä field.

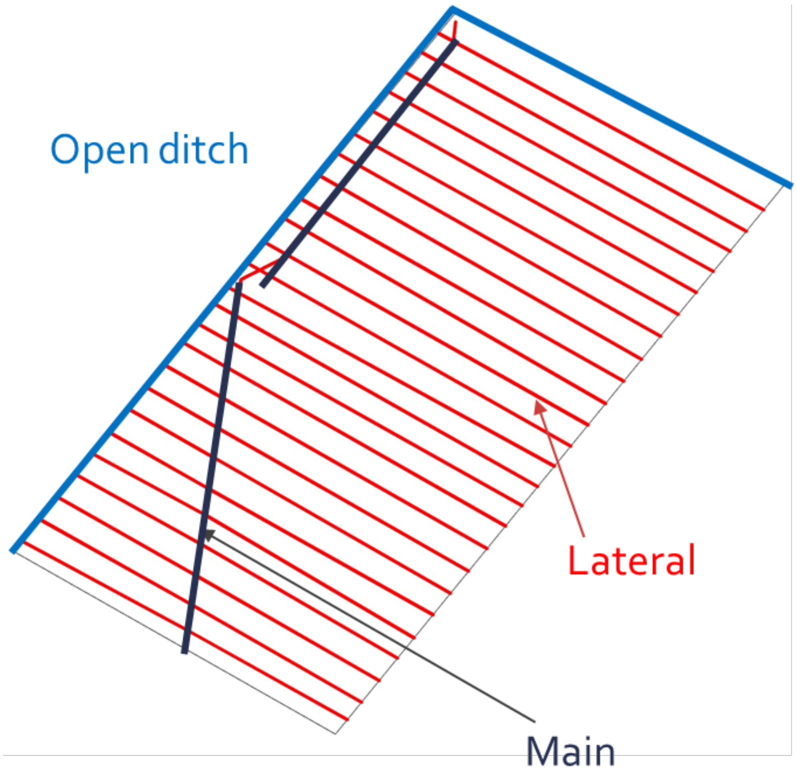


Figure 16: Schematic representation of tile drainage in the Tyrnävä Field

A transient model (without tile drainage) with a daily time step has been run for the period of 2007 to 2019 to illustrate the current progress of the model. Figure 17shows the simulated head in the field during the high and low flow periods. The numerical implementation of tile drainage is in progress. The model is still under development, so the results of the model scenarios will be evaluated and discussed in the future deliverables under this project.

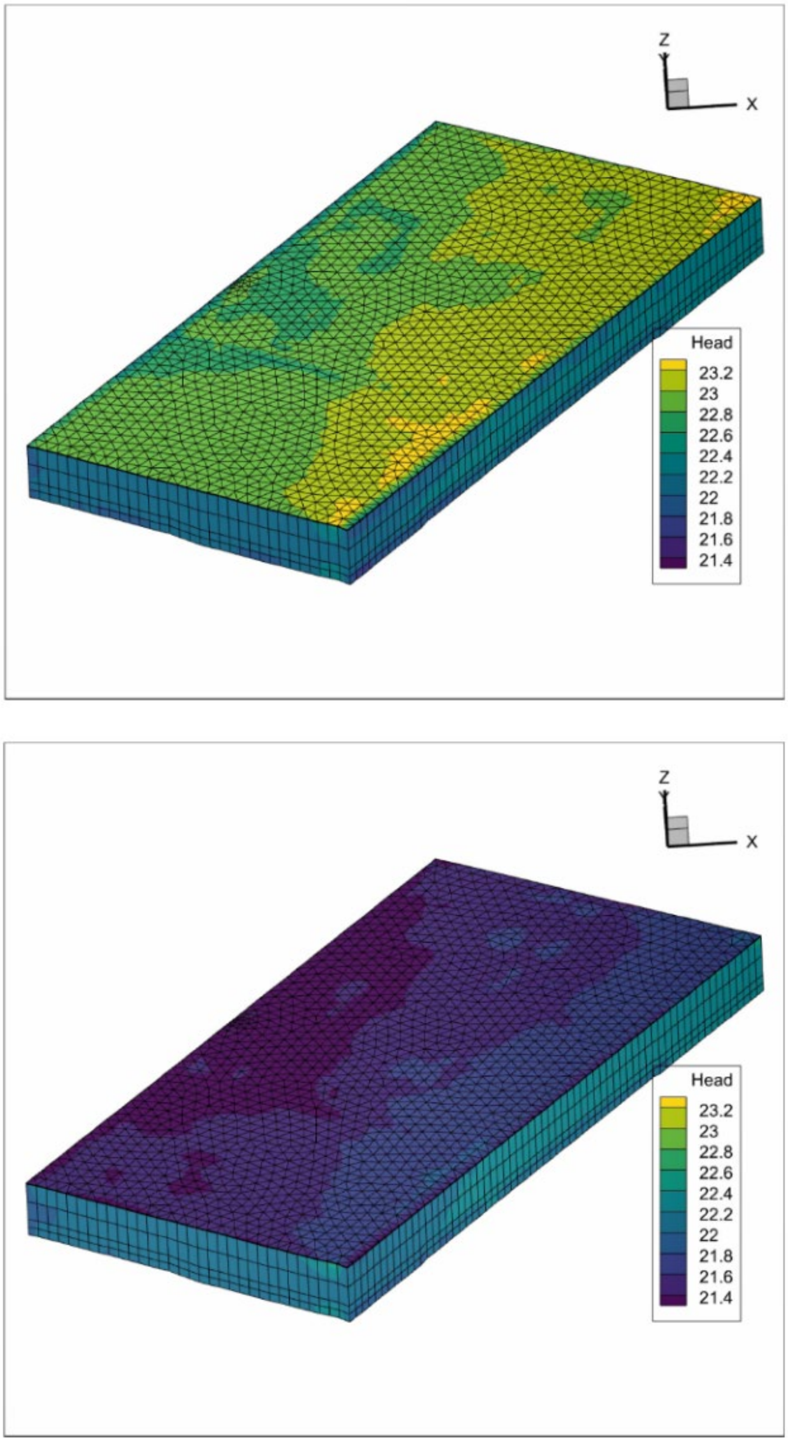


Figure 17: Simulated head (m) during the high (top) and low (bottom) flow periods.

3.3 Case study 2 - Municipality of Ruukki (Finland 2)

3.3.1 General overview

Table 8: General overview – Case study 1

Case study	WATERAGRI solutions	Partner involved
Finland II 	Physical modelling (HydroGeoSphere) (A2) Tracers (B7) Bio-membranes (C3)	Leader: OULU Participants: BOKU, VTT and OULU

3.3.2 Updated implementation and research plans

Table 9: Updated implementation plan – Case study 2

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
Measurements will be running in long term in Ruukki field station and continued also after the WATERAGRI project. Modelling (A2) work has been started and tracer (B7) samples collected and will be continued during the WATERAGRI project period. Testing of membranes (C3) is not yet active but will be planned during 2021 (water quality sent to VTT and tested in Helsinki). Key stakeholders are local farmers and agricultural associations.	• New in-situ high resolution sensor installed and in testing. • Hydrological and water quality analysis is ongoing and progressing. • Sub-irrigation and water storage system building at winter 2021/22 and first sub-irrigation experiments in 2022. • DRAINMOD software was built and calibrated to all 6 field blocks in the Ruukki site. The model was successfully built but calibration turn out to be challenging. The project continues to improve calibration to the site, but local soil structure in cultivated and inability to include regional main drainage system to the model seems to be the main challenge in DRAINMOD calibration. • Water quality and loading analysis from cultivated and controlled drainage peatland fields: data collection, analysis and starting to write the results

Table 10: Updated research plan – Case study 2

Plan after M9 (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
See details in implementation plan	We continue our research on (i) the field-scale water balance and observe the effectiveness of drainage management on WTL control/manipulation to reduce GHG emissions whilst maintaining biomass production, (ii) catchment-scale water retention (B7) and balance analysis for controlled drainage and irrigation needs.

3.3.3 Data availability and data provision

Table 11: Data availability – Case study 2

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
1) Availability of data	
Data are measured and are available on request	Hydrological and water quality analysis is ongoing and progressing. Following data are measured and are available on request. Monitoring 2018-2021: • Continuous: Groundwater table levels, drainage flows, soil moisture. • Frequent: Stable water isotopes, hydraulic conductivity, GHG fluxes. • Seasonal: soil-water retention, biomass yield.
2) Data that are planned to be measured	
No further installations planned l	New real-time monitoring (WT, moisture) and automatic WT control system installation in 2022 Monitoring 2022: • Continuous: Groundwater table levels, drainage flows, soil moisture. • Frequent: Stable water isotopes, hydraulic conductivity, GHG fluxes. Seasonal: soil-water retention, biomass yield.

Table 12: Current status of data provided – Case study 2

Which data have been made available to be included in the database until date?	Following data are available on request. Monitoring 2018-2021: • Continuous: Groundwater table levels, drainage flows, soil moisture. • Frequent: Stable water isotopes, hydraulic conductivity, GHG fluxes. • • Seasonal: soil-water retention, biomass yield.
Which data will be available to be included in the database within this year? (e.g., until end of September 2022)	Following data are available to be included on request in the database within the next year. Monitoring 2022: • Continuous: Groundwater table levels, drainage flows, soil moisture. • Frequent: Stable water isotopes, hydraulic conductivity, GHG fluxes. • Seasonal: soil-water retention, biomass yield.

3.3.4 Photo documentation

This section gives photo documentation on implemented and ongoing work in the Ruukki case study area.

Finland's Ruukki field study site is mainly a grass cultivation site and a major experimental site conducting several experiments administered and monitored by the Natural Resources Institute Finland (LUKE). The Ruukki field has been facilitated by 6 different drain blocks (Figure 18) that drain the water from the entire field. Several hydrometeorological data measuring instruments were installed to collect the data from the field and for further analysis. Automated GWT loggers and drainage data monitoring instruments were also installed (Figure 19). The weather data were collected from the FMI's weather station adjacent to the Ruukki field site. Collected groundwater table and precipitation data are shown in Figure 20.

DRAINMOD software was built and calibrated to all 6 field blocks in the Ruukki site. The model was successfully built, but calibration turn out to be challenging. The project continues to improve calibration to the site. Water quality and loading analysis from cultivated and controlled drainage peatland fields are in progress.

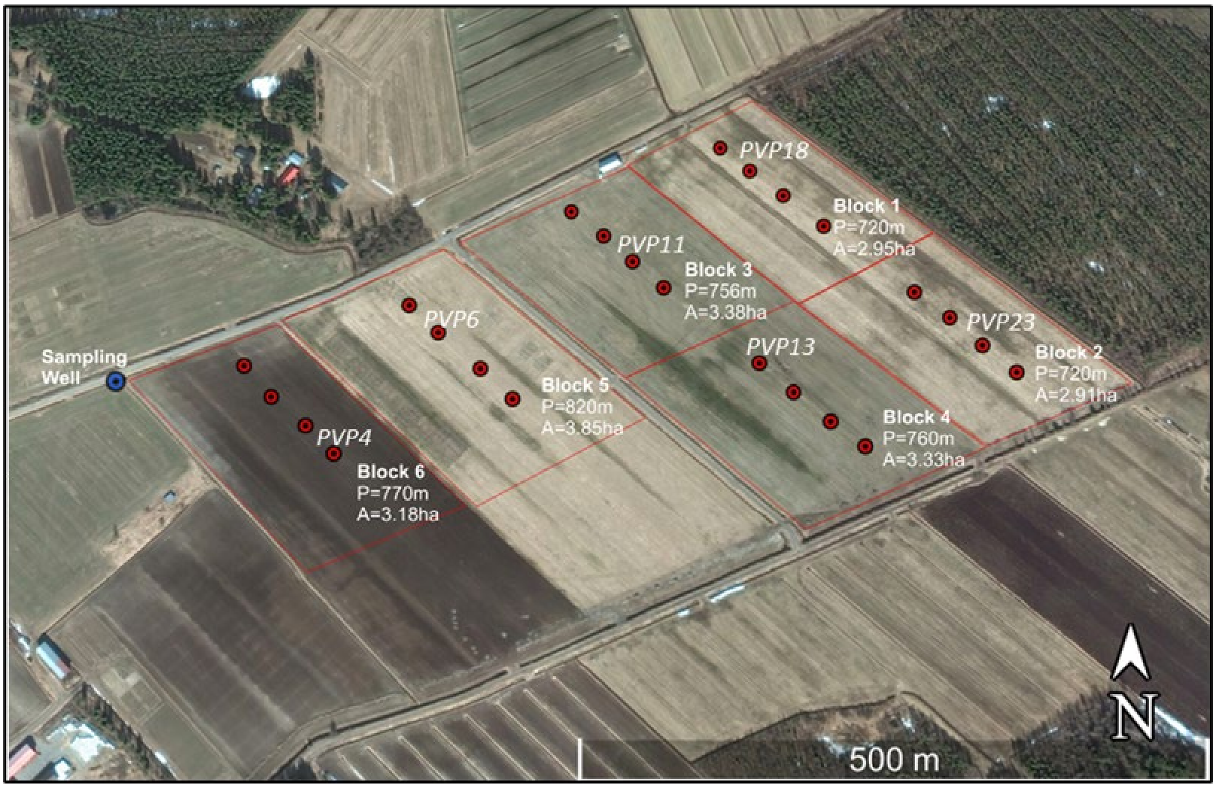


Figure 18: Experimental setup at Ruukki site

Figure 19: Ruukki field site with automatic groundwater table (bottom left) and drainage (bottom right) measuring instruments.

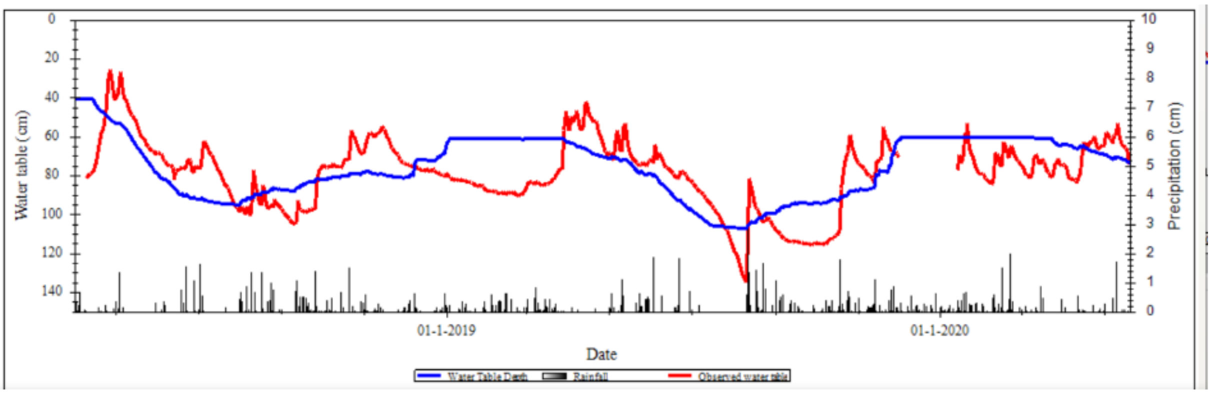


Figure 20: Groundwater table and precipitation in the Ruukki site from 2018 to 2020

3.4 Case study 3 - Gårdstånga Nygård (Sweden)

3.4.1 General overview

Table 13: General overview – Case study 3

Case study	WATERAGRI solutions	Partner involved
Sweden 	Wetlands (B1+C1) Water retainer (B5) DET apparatus (B8)	Leader: GN Participants: ULUND, USAL, BZN and GN

3.4.2 Updated implementation and research plans

Table 14: Updated implementation plan – Case study 3

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
ULUND has requested that GN commences testing biochar immediately. GN is in contact with Biochar suppliers hoping to be able to meet these wishes. This is all dependent on what is growing in the fields and when it is time for harvest. In this case we will harvest our fields in August 2021 and will implement the tests with Biochar in the ground as well as constructing the irrigation in September 2021. This will benefit harvest of 2022 onwards	Skånefrö AB will supply the Biochar at production cost. Biochar has to be mixed into the field, preferably by ploughing or cultivating the field. As such we will plough or cultivate the field after harvest in August 2022 and then create two 50 by 50 meter plots with biochar. In parallel, GN will have two 50 by 50 meter plots without biochar. Irrigation will be added, and we shall then be able to compare what happens with or without the two parameters.

Table 15: Updated research plan – Case study 3

Plan after M9 (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
GN will provide a new test site closer to the irrigation dam, which will allow for an earlier start to the project. GN will provide a large and flat field with almost homogenous soil structure. The field will comprise of 16 parcels. (Details see D5.1)	A 30,000 m^2 large and 3 m deep dam has been constructed in the corner of a field at GN, located 10 km north of Lund, Sweden. The pond will hold 90,000 m^3 of water that can be used for irrigation during vegetative periods. The sustainable flood retention basin (SFRB) was constructed and started its operation in December 2020. In May 2021 we found out the

dam was leaking. The dam was repaired in October 2021.Gårdstånga Nygård (GN) has provided a test field (close to the SFRB), which is a large and flat field with almost homogenous soil structure. The field comprises 64 parcels (each is 12 m × 12 m). In the experiment, three variables were tested (four replicates each): irrigation, water retainer product and phosphorus. There are 16x4 parcels and 4 controls. The treated water by SFRB was used for irrigation of spring barely during June to August 2021 as well as early September 2021. The Spring Barely has been harvested and the yield is currently being assessed. However, initial findings indicate that the compacted soil (during construction of the SFRB) did not support a good harvest for 2021. Delayed arrival of machinery and irrigation equipment resulted in irrigation only being rarely applied before it started to rain again. GN has now acquired irrigation equipment for the WATERAGRI project.

GN will provide a further test site close to th irrigation dam, which will allow for an expansic of the project. GN will again provide a large an flat field with almost homogenous soil structure

GN has acquired a hand-held soil sampling machine including moisture, nutrients, and pH analysis (STENON Farm Lab).

The new irrigation system will be fully functional by April 2022. Winter Wheat was selected as the next crop in the six-year crop rotation plan.

The ULUND research team is analysing collected water samples for physical and chemical quality.

The ULUND team has sent all collected soil samples for detailed analysis to a Hungarian laboratory. GN has sent all its collected soil samples to the same laboratory in Hungary.

The harvested spring barely has been assessed for quantity and quality analysis by an external third party (Hushållningssällskapet)

	and the data are being analysed. All data from the analysis will be disseminated via scientific reports and publications by ULUND

3.4.3 Data availability and data provision

Table 16: Data availability – Case study 3

Original plan (January 2021, i.e., D5.1)	**Updated plan (M24, April 2022)**
1) Availability of data	
All data which are measured can be used because they belong to GN.	All collected data were saved in the ULUND repository, and all data will be accessed for publication purposes later on.
2) Data that are planned to be measured	
See master thesis "*Water quality and water availability at Gårdstånga Nygård*" by Lina Lennklev (supervisor: Magnus Persson): https://lup.lub.lu.se/student-papers/search/publication/9018891 l	ULUND research team measuring the SFRB water quality, field soil quality, and assessing crops growth and yield quality. All collected data were saved in the ULUND repository. GN has acquired a STENON Farm lab hand-held soil sampling machine to estimate parameters including moisture, nutrients and pH. ULUND will use water level meters to measure the water level in the SFRB.

Table 17: Current status of data provided – Case study 3

Which data have been made available to be included in the database until date?	All collected data were saved in the ULUND repository.
Which data will be available to be included in the database within this year? (e.g., until end of September 2022)	All collected data were saved in the ULUND repository, and all data will be accessed for publication purposes later on.

3.4.4 Photo documentation

Gårdstånga Nygård (GN) manages 200 ha of organic and 800 ha of conventional farmland, which is vulnerable to droughts. The conventional cultivation is undertaken according to FAO's principles of conservation agriculture. The expected impact of applying the WATERAGRI framework in addition to improving the planting sequence and field management will comprise improved soil health, reduced leaching of nutrients and decreased carbon dioxide emissions from the soil. Sustainable water retention management also includes the construction of a sustainable flood retention basin (SFRB) used both as a wetland for biodiversity enhancement and irrigation purposes. The total costs were about €560,000, and the majority came from Gårdstånga Nygård (GN). The SFRB is receiving inflow from a local stream, which functions like a vegetated ditch channel system.

A 30,000 m^2 large and 3 m deep dam has been constructed in the corner of a field at GN, located 10 km north of Lund, Sweden. The pond will hold 90,000 m^3 of water that can be used for irrigation during vegetative periods. The SFRB was constructed and started its operation in December 2020 (Figure 21 and Figure 22).

Figure 21: Dam construction at Gårdstånga Nygård (GN), Sweden.

Figure 22: Dam Operation at Gårdstånga Nygård (GN), Sweden.

ULUND will assess the direct recovery and reuse of nutrients from eutrophic water bodies for growing crops by testing different configurations of farm constructed wetlands in Sweden at Gårdstånga Nygård (GN). As the SFRB is currently not eutrophic, this task could not be meaningfully completed at least for the first growing season in summer 2021. For the time being, GN is also planning to use only the new SFRB for irrigation purposes. However, summer 2021 was a rather wet year, and the crops received almost no irrigation water.

ULUND and GN are also evaluating wetland sediment recycling applications for the new SFRB and other wetlands at GN. The Swedish case study site will be used as a feasibility study supported by a review on risks linked to contamination and legislative barriers. Outcomes will provide guidelines for future applications.

The wetland effluent will be used for irrigation purposes in future growing seasons. Food crops will directly benefit from remaining nutrients in the pre-treated effluent of the SFRB.

Gårdstånga Nygård (GN) has provided a test field (close to the SFRB), which is a large and flat field with almost homogenous soil structure. The field comprises 64 parcels (each is 12 m × 12 m). In the experiment, three variables were tested (four replicates each): irrigation, water retainer product and phosphorus. There are 16 × 4 parcels and 4 controls (Figure 23).

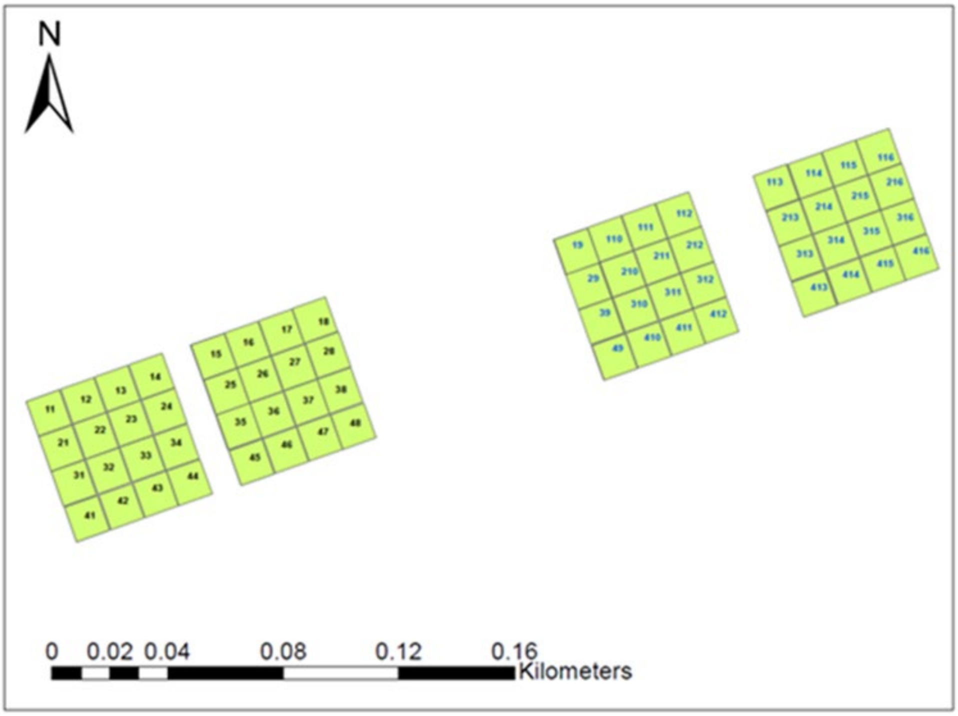


Figure 23: GN digitised map and the location of wetland plots at Gårdstånga Nygård, Sweden. The GPS coordinates were obtained during the field work in April.

The water collected and treated by the SFRB was used for irrigation of spring barely between June and August 2021 (Figure 24) as well as early September 2021. The spring barely has been harvested and the yield is currently being assessed (Figure 25). However, initial findings indicate that the compacted soil (during construction of the SFRB) did not support a good harvest for 2021. Heavy rainfall also resulted in irrigation only being applied rarely.

Figure 24: Spring Barely plants in Gårdstånga Nygård (GN), Sweden.

Figure 25: Spring barely plants harvesting at Gårdstånga Nygård (GN), Sweden.

The ULUND research team undertook the following activities (Figure 9):

- Visiting the farm monthly for water and soil sampling and analysis
- Harvest production and quality analysis
- USAL and ULUND tested the DET apparatus for sludge obtained from a mature wetland (not the new SFRB) at GN by using two types of filter papers (CST and BF3) showing that the CST filter papers required more time for dewatering the sludge than the BF3 ones when measuring the average time, minimum time, maximum time, and center time, while the standards deviation percentage values for the BF3 paper were the highest.

Figure 26: Figure 9: ULUND research team activities at Gårdstånga Nygård (GN), Sweden.

3.5 Case study 4 - Auxerre (France)

3.5.1 General overview

Table 18: General overview – Case study 4

Case study	WATERAGRI solutions	Partner involved
France 	Water retainer (B5) Microfluids technology (C5).	Leader: INRAE Participants: BZN, INRAE and Agricultural Chamber of Yonne

3.5.2 Updated implementation and research plans

Table 19: Updated implementation plan – Case study 4

Original plan (January 2021, i.e. D5.1)	Updated plan (M24, April 2022)
1. Water Retainer	Achieved for 2021, implemented for the second year (2022)
2. De novo design of the territory project and of innovative cropping systems and landscape infrastructure	Agreed by the main stakeholders. 3 first design workshops realized in December 2021 and January 2022
3. Step by step design of the territory project	Begun for Nitrate water quality with monitoring of Soil N min (2020, 2021).
The collection of data about soil N content, crops on the whole catchment area and main practices into the 10 farms will be realized from autumn 2020 until autumn 2023.	Data collection is going on for soils, and for crop sequences. Manually collected water samples for quality analyses (110). The instrumentation for water quality measurements have been chosen.

Table 20: Updated research plan – Case study 4

Plan after M9 (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
1. Water Retainer	To be analized in collaboration with BZN
2. Design workshops using a serious game	Still waiting the serious game prototype
3. Water quality results	110 samples already collected, still to be analysed

4. Soil results and fields practices	Results of 2020 and 2021 N soil content collected and analysed

3.5.3 Data availability and data provision

Table 21: Data availability – Case study 4

Original plan (January 2021, i.e., D5.1)	**Updated plan (M24, April 2022)**
1) Availability of data	
Data are measured and are available on request	
2) Data that are planned to be measured	
For:	
1. Water Retainer	Available for BZN and INRAe
2. De novo design of the territory project and of innovative cropping systems and landscape infrastructure	Not available yet
3. Step by step design of the territory project	Not available yet
in more than 10 farms in each of their field inside the territory	N soil contents available for INRAe

Table 22: Current status of data provided – Case study 4

Which data have been made available to be included in the database until date?	• Water retainer results • 2020 N soil content
Which data will be available to be included in the database within this year? (e.g. until end of September 2022)	• 2021 N soil content • First results of the design workshop

3.5.4 Photo documentation

The following pictures show selected activities within WATERAGRI at case study 4.

Figure 27: Water Retainer Experimentation. June 2021.

Figure 28: Framers’ design workshop. Saint Privé France. 17 January 2022.

Figure 29: Water Quality Les Bonneaux stream. Saint Privé France. 2022.

3.6 Case study 5 - Selhausen (Germany)

3.6.1 General overview

Table 23: General overview – Case study 5

Case study	WATERAGRI solutions	Partner involved
Germany 	Physical modelling (A2) Remote sensing pipeline (B2). Microfluids technology (C5).	Leader: FZJ Participants: FZJ and INRAE

3.6.2 Updated implementation and research plans

Table 24: Updated implementation plan – Case study 5

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
All relevant data types can be obtained from the installed sensors. In addition, we expect to use also remote sensing information to further constrain model simulations and improve model predictions of soil and crop status. The measurement data are available, but the Terrestrial Systems Modelling Platform (TSMP) still has to be setup for the Selhausen site. In addition, a pipeline is defined which allows measurement data to be stored in a database, and to be assessed in near-real time for using them in data assimilation procedures. The near-real time assessment still has to be established, as well as the further development of the data assimilation platform to include the assimilation of vegetation related variables. It is expected that the solution can be implemented until the 30th of April 2022. We have a delay of one year contracting a postdoc, related to the Covid19-situation. The demonstration of the solution is planned the year afterwards, until beginning 2023. We will combine the TSMP model for the Selhausen site, the in situ and remotely sensed	Richard Hoffmann was hired as a new postdoc in July 2021. Recruitment was delayed by a year due to the Covid19 pandemic. The setup of the Terrestrial Systems Modelling Platform (TSMP) for Selhausen site, including the interface upgrade to CLM v5.0 and Parflow v3.8, began in M15-M18. In M24, the development of a spatially distributed CLM-ParFlow model for the German site including feedback from Workshop #3 is in progress. The model size is 5 km x 5 km x 50 m. Workshop #3 lead by FZJ was successfully conducted in M21 (regional meetings) and M22 (plenary session), where stakeholders' needs for physically based models in the context of weather and climate resilient agriculture were collected. Valuable feedback from stakeholders was processed and transferred into actions for the modelling part at the German site. For example, stakeholders asked for hydrological information at the field scale and would like to get provided with management strategies derived from model solutions. This requires local models with, for example, grid cell sizes of about 20 m x 20 m x

measurement data, weather predictions, and the data assimilation procedure, to make predictions of terrestrial system states like soil moisture content and crop status. The predictions will be evaluated with independent data not used in the assimilation. Water quality samples to support the microfluidics technology will be taken in 2021. The agricultural chamber of North-Rhine-Westphalia and local farmers in Selhausen will be involved in this action.	1 m to cover about 50 parcels of about 100 m x 100 m in the sub-catchment of the Rur River at the German site. We are developing also single point CLM (version 5.0) models, as these solutions can be provided faster. We collect data from sensors installed at the German site to be used in data assimilation procedures. The development of the near-real-time assessment and assimilation of vegetation-related variables in TSMP is also in progress.

Table 25: Updated research plan – Case study 5

Plan after M9 (January 2021, i.e., D5.1)	**Updated plan (M24, April 2022)**
2021: Local water samples to be treated with microfluidics technology.	Local water samples have not been taken yet, which will be done soon.
April 2022: TSMP-model for Selhausen ready, data pipeline including near-real time data access established, data assimilation capacities enhanced to assimilate vegetation related information.	During M15-M24 the physically based model for the German site is being developed, including also the feedback collected from Workshop #3 (Table 24).
April 2023: Showcase for Selhausen site mimicking near real-time prediction of terrestrial system model states, relevant for agricultural practices. Simulations will be done for different scenarios; the scenarios vary according to the type and amount of the assimilated measurement data, and the technical settings for the data assimilation procedure.	For 2022 and 2023, open loop runs, and soil moisture data assimilation runs are planned (with and without parameter estimation). Next, assimilation of leaf area index measurements from drone will be tested. We will evaluate different sets of parameter combinations which will be updated. The goal is to predict land surface and subsurface states and fluxes (e.g., soil moisture, crop yield) with the single point CLM v5.0 model and the spatially distributed CLM-ParFlow model offline, mimicking an operational approach, for 14 days forecasts.

3.6.3 Data availability and data provision

Table 26: Data availability – Case study 5

Original plan (January 2021, i.e., D5.1)	**Updated plan (M24, April 2022)**
1) Availability of data	
None	n/a.

2) Data that are planned to be measured	
In addition to the already measure0d date, in the area an eddy covariance station is located which provides time series for land-atmosphere exchange fluxes of water (evapotranspiration), energy (sensible heat flux) and carbon flux. Since 2015 also four closed dynamic chambers have been monitoring soil respiration, i.e., CO2 emission from the soil. In addition, in the area regularly campaigns were carried out. A geophysical campaign (Electromagnetic Induction) combined with in situ soil investigation resulted in a 1m resolution soil map for the site. In the year 2020 several drone flights have been carried out for mapping of the crop status including leaf area index. Also, for the coming years, measurement campaigns are planned which will provide more detailed information on the crop status, which can be used to improve the simulation models for the site.	The collection of (micro)meteorological, hydrological, vegetation and soil data (time series) were continued and the respective data successively stored in the TEODOOR database. It will be further continued. Data can be freely accessed.

Table 27: Current status of data provided – Case study 5

Which data have been made available to be included in the database until date?	A continuous monitoring network is installed at Selhausen site, providing (micro) meteorological, hydrological, vegetation and soil data (time series) that are successively stored in the TEODOOR database. This is complemented by specific field experiments. Data until end of April of 2022 is: ***<u>2020:</u>*** e.g., Drone flights measuring leaf area index ***<u>Since 2015:</u>*** - *Wireless sensor network* measures soil moisture, soil temperature and soil heat flux in near real-time measured in five profiles (-0.01 m, -0.05 m, -0.1m, -0.2 m, -0.5 m and -1 m) that is remotely available - In addition, four closed dynamic chambers provide information on CO2 emissions from the soil

	Since 2011 - Phenological developments of crops and farming activities are continuously monitored - The *Eddy Covariance Station (EC)* measures three-dimensional wind component, land-atmosphere exchange fluxes of water, carbon and energy, air temperature, air humidity, net radiation (incoming and outgoing short- and long-wave radiation), photosynthetic photon flux density and precipitation. • The *Multi parameter probe (next to EC station)* measures natural groundwater level, groundwater electrical conductivity and groundwater temperature are continuously measured
Which data will be available to be included in the database within this year? (e.g., until end of September 2022)	The mentioned monitoring network will continue to collect time series in 2022 and may be complemented by new field experiments.

3.6.4 Photo documentation

The physically based model for the German site (Selhausen) is being developed with the Terrestrial System Modelling Platform (TSMP). TSMP consists of compartment models for the atmosphere (COSMO), the land surface (CLM) and the subsurface (ParFlow). In this work only, the land surface and subsurface components will be used (Figure 6). The model will be forced by spatially varying information on precipitation, other meteorological variables such as global radiation, land use, crop types, and hydro(geo)logical properties. Data collected by an all-in-one weather station, a cosmic ray neutron sensor for measuring soil moisture over a range of about 250 m, and in situ soil moisture and soil temperature sensors installed at the Selhausen site are available remotely and are sent to a database (Figure 30a,b). The data assimilation framework PDAF coupled to TSMP allows model simulations to be corrected with measurements. In this way, model states and fluxes will be updated in real-time and stay closer to their true counterparts. Model parameters will also be constrained by data assimilation. Real-time measurements for the data assimilation step will be collected from spatially distributed hydrological measurement systems with high temporal resolution and accuracy. In addition, groundwater data, remote sensing data and measurements of leaf area index from drone overflights are available and will also be used for model calibration, data assimilation and forecasting. The system will provide the best possible prediction of variables like soil moisture content, groundwater level, crop status, and crop yield. The predictions will be made available online in the form of graphs, maps and tables (Figure 30c).

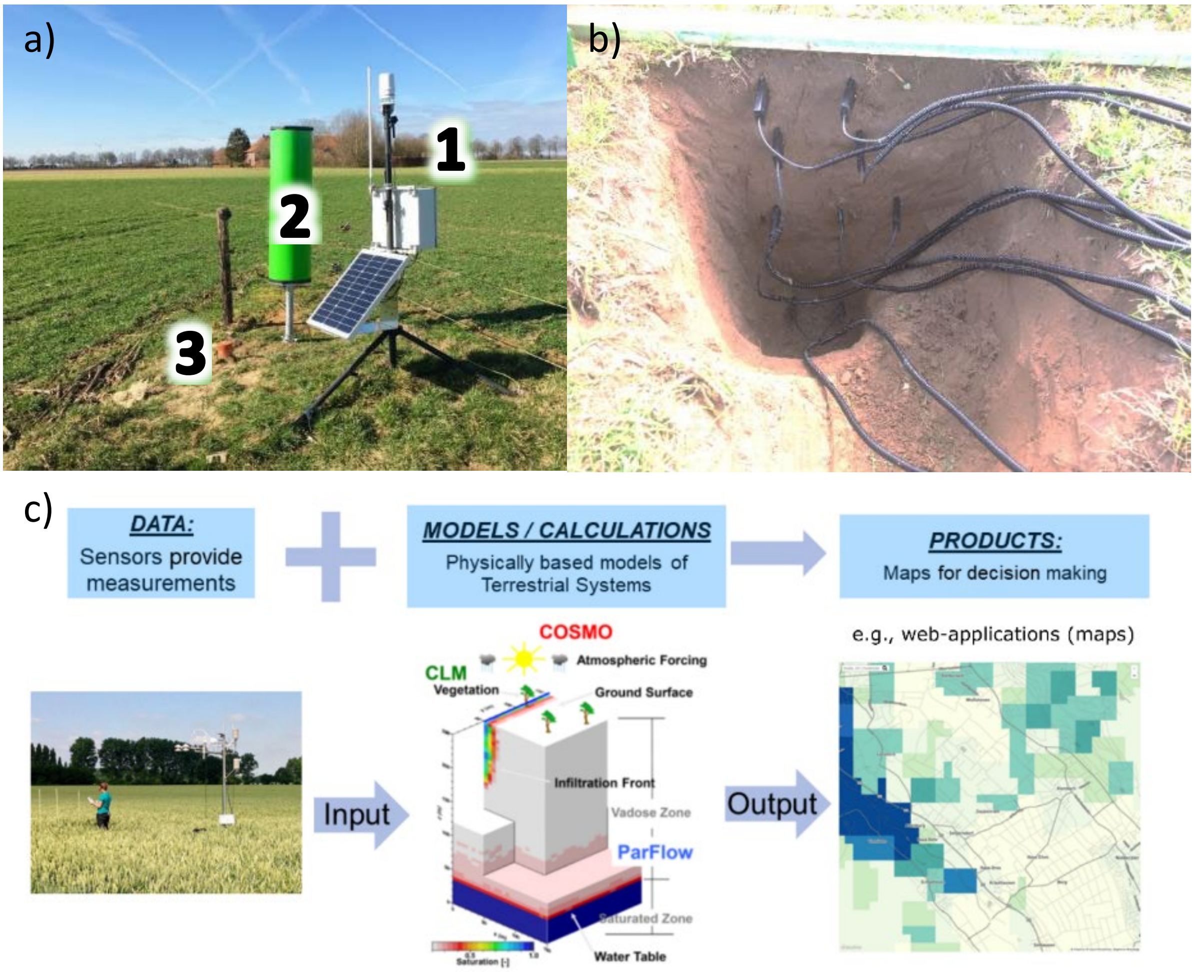


Figure 30: Pictures showing the implementation of WATERAGRI solutions at case study 5.
a) Hydro-meteorological measurement system for real time measurements at German site 'Selhausen' (1: All in one weather station (ATMOS-41), 2: Cosmic Ray Neutron Sensor, 3: Soil moisture and temperature sensors).
b) Soil moisture measurements at one location and at different depths.
c) The modelling workflow: The physically based model for the German site 'Selhausen' (5 km x 5 km x 50 m) will be forced by spatially varying data collected from weather services and measured on-site. Results will be made available in graphs, maps and tables, i.e., in a format that stimulates the needs mentioned by stakeholders in Workshop #3 as best as technically possible.

3.7 Case study 6 - Lower Silesia (Poland)

3.7.1 General overview

Table 28: General overview – Case study 6

Case study	WATERAGRI solutions	Partner involved
Poland 	remote sensing pipeline (B2) optimize irrigation water (B3 and B4) water retainer product (B5) dewaterability estimation test (B8)	Leader: UPWr Participants: BZN, AGRICOLUS, VULTUS, USAL, UNINE, and UPWr

3.7.2 Updated implementation and research plans

Table 29: Updated implementation plan – Case study 6

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
From January until June 2021 young model developer from UPWr will be trained in UNINE to use HydroGeosphere software for building numerical model of small agricultural catchment located in Poland. The proposed modelling technology (A2) will be used to allow the development of real-time irrigation schedule modelling (B3).	Arkadiusz Głogowski spent 6 months in UNINE to learn HydroGeosphere software. Preliminary physical-based model of Polish agricultural catchment was built. The calibration process is ongoing.

Table 30: Updated research plan – Case study 6

Plan after M9 (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
New observation network was set up in December of 2020 by UPWr. The measurements will collect in 5-min intervals and stored online in a cloud database. The collection of data will take place to the end of the project.	The observation network is fully operational, and all registered data are being stored in a cloud database. A graphical interface is available to analyse the data. The collection of data is ongoing.
The dewaterability estimation test (B8) apparatus was delivered by USAL in 2020. UPWr has performed tests using soil samples from the study site field in order to assess	DET was used to test soil samples. The analysis of results is ongoing.

The water retainer product (B5) will be delivered by BZN in the spring of 2021 and tested at two pilot plots of 1 ha where oats will be cultivated. Soil moisture measurement devices at various depths will be used for the evaluation of the product.	The water retainer product was applied over 3 ha of oats crop in 2021. Soil moisture distribution in 4 soil profiles was monitored during whole growing season. The yield from 3 treated plots and one untreated plot were obtained. In March 2022 the Water Retainer was applied over 1ha of barley and 1 ha of wheat in new locations. The soil moisture sensors were moved from previous locations to monitor the soil moisture in soil profiles.
Remote sensing pipeline (B2) developed by VULTUS will be tested in 2021 to monitor the soil moisture at the field scale, crop condition, vegetation disturbances; phenological phases of crops and vegetation density.	Remote sensing pipeline was tested to monitor the soil moisture at the field scale and phenological phases of crops.
To support microfluidic (C5) nutrient recovery technology UPWr will develop a GIS-based approach for mapping overland flow pathways from surrounding areas to surface water and detecting zones with a tendency for excessive surface runoff accumulation.	GIS-based approach for mapping overland flow pathways is under development. Preliminary maps of overland flow pathways are available.

3.7.3 Data availability and data provision

Table 31: Data availability – Case study 6

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
1) Availability of data	
None	Measurement data are stored in the cloud database and are ready to be transferred to the WATERAGRI geodatabase.
2) Data that are planned to be measured	
In December 2020 the following data started to be measured in the Polish case-study site: • soil moisture and temperature at 8 depths with 10 cm vertical distance in 4 locations, • groundwater table depth and temperature in 4 locations,	As planned, all parameters are continuously monitored at the 10 min interval. The data are stored in a cloud database.

- water level and temperature in the stream,
- air temperature at 2m and 4m height,
- humidity at 2m and 4 m,
- wind speed and direction at 4 m,
- intensity and cumulative value of precipitation,
- global irradiance,
- sunshine duration.

Table 32: Current status of data provided – Case study 6

Which data have been made available to be included in the database until date?	Measurements collected by the sensors: meteorological data, groundwater levels, stages of surface water, soil moisture profiles are ready to be transferred into the database. The processed data (aggregated) are available on request. Land use and soils map were saved in the ULUND repository.
Which data will be available to be included in the database within this year? (e.g., until end of September 2022)	Crops logs for 2020 – 2022 are regularly updated in the AGRICOLUS platform. Water quality in ground water and surface water is continuously monitored. Retention curves for selected soil profiles are available until end of June 2022. Rating curve for the outlet of the catchment will be constructed until end of October 2022.

3.7.4 Photo documentation

The following pictures show selected activities related to the WATERAGRI solutions at case study 6.

Figure 31: The observation network installed in case study 6.

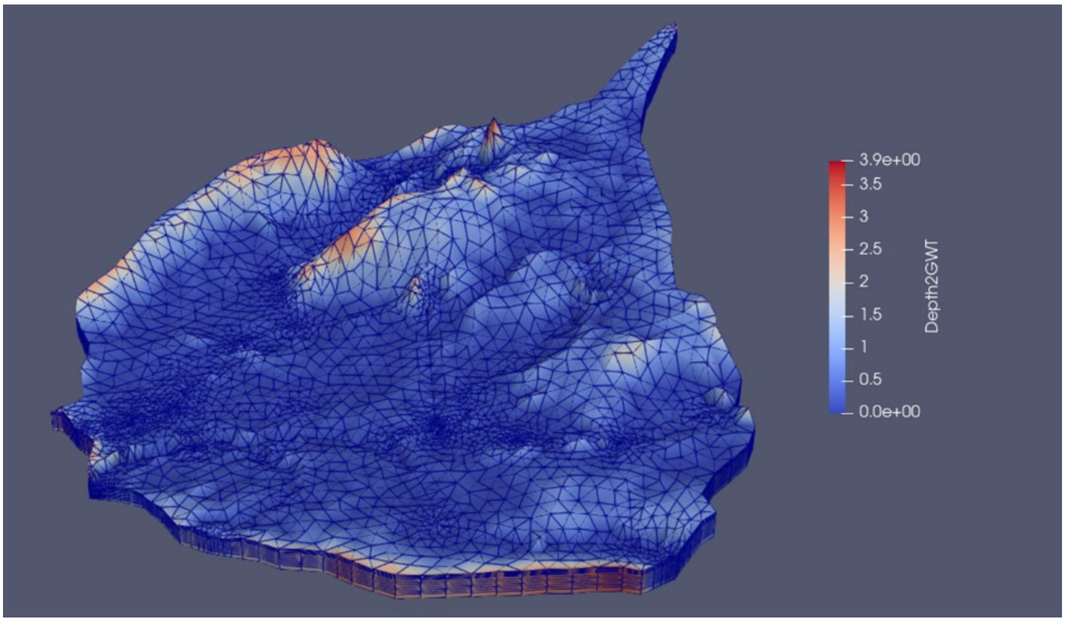


Figure 32: Numerical model of the catchment in case study 6.

Figure 33: Field application of Water Retainer at case study 6.

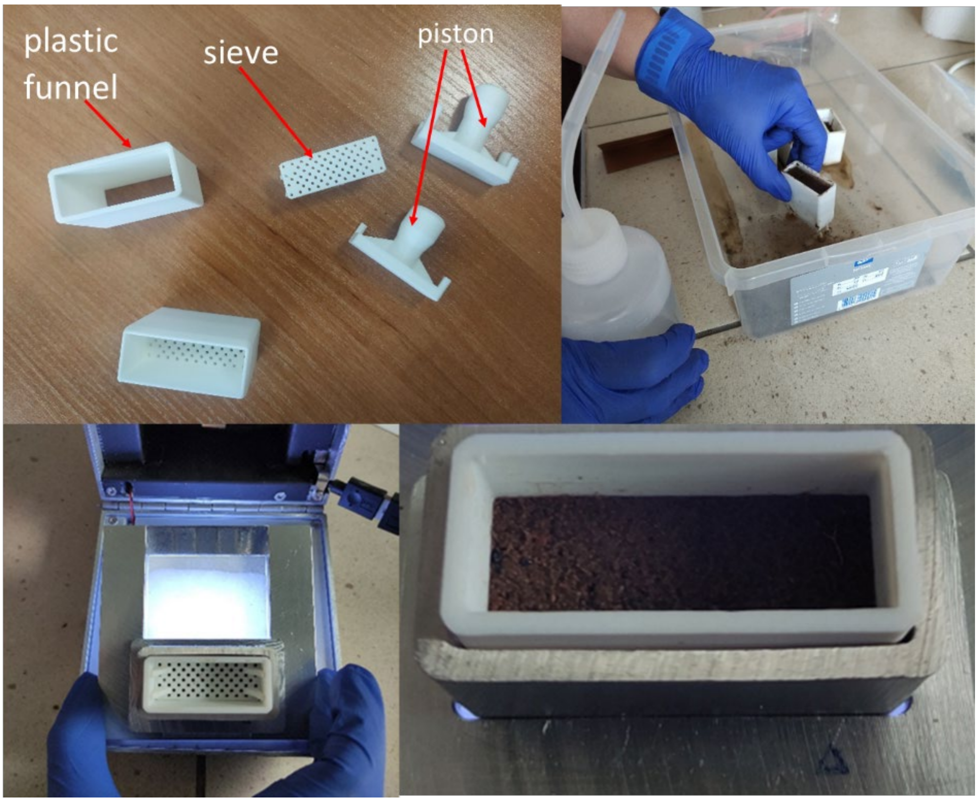


Figure 34: Adaptation of DET device for analysing soil samples.

3.8 Case study 7 - Seeland (Switzerland)

3.8.1 General overview

Table 33: General overview – Case study 7

Case study	WATERAGRI solutions	Partner involved
Switzerland 	Physical modelling (HydroGeoSphere) (A2) Irrigation (B3+B4)	Leader: UNINE Participants: FZJ, OULU and UNINE

3.8.2 Updated implementation and research plans

Table 34: Updated implementation plan – Case study 7

Original plan (January 2021, i.e., D5.1)	**Updated plan (M24, April 2022)**
Year 1: The existing online sensor network will be expanded, and a new real-time modelling framework developed in collaboration with FZJ. Year 2: Development of the real-time modelling framework will continue, and synthetic modelling experiments will be conducted, testing the efficiency of soil water retention solutions on local and catchment scale. Year 3: Case study specific management questions will be tackled, and suitable solutions developed in WATERAGRI will be tested with the new real-time modelling framework, aiming at providing an integral management of groundwater, surface water, drainage and irrigation under optimized water use and for a reduced cost. For this, local farmers, farmer associations, authorities and engineering companies will be consulted. Year 4: An optimized water management system based on the new real-time modelling framework will be put in place at the study site. Improved farming practices will be developed using solutions developed in WATERAGRI and the real-	• Installation of online sensor network completed • Development of new real-time modelling framework for HydroGeoSphere is still ongoing. • Synthetic modelling evaluation of soil water retention solutions are ongoing (in collaboration with UPWr and USAL) • Progress on the development of the numerical HydroGeoSphere model for the field site. • New machine-learning-supported method for the generation of 3-D subsurface maps of soil hydraulic parameters from soil profile databases, environmental covariates, the European pedotransfer function database euptfv2 and published peat soil pedotransfer functions in active development. The maps will allow unprecedented parametrization accuracy of soils in physically based flow models.

time modelling framework in collaboration with FZJ. Data and results will be included in the framework decision support system and visual interface in collaboration with AGRICOLUS.	

Table 35: Updated research plan – Case study 7

Plan after M9 (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
For selected field sites, including the Seeland case study site, physically-based modelling will be developed by UNINE and FZJ. Moreover, a set of automatic procedures will be developed to acquire the sensor data from each site, harmonize them and transfer them to the WATERAGRI Geodatabase developed in WP2 (FZJ, UNINE and AGRICOLUS). The models will access the data directly in the database and a script will produce the model input in the format required by the models. Within the cloud, all data will be stored using a framework allowing for information extraction by different tools and models later on. In addition to online field-based data, the physical based models are continuously receiving information on the irrigation water requirements (provided through the AGRICOLUS *water balance model*), thus connecting the surface water demands with the hydraulics across the entire catchment. The physically based models are also developed with the goal to assess the implications and the efficiency of the different soil water retention solutions. Modifying soil properties is at the core of increasing soil water retention using the proposed biodegradable soil water retainer and biochar. A quantitative understanding on how these products affect the physical characteristics of the soil (e.g., soil water retention curve) is thus required to understand how efficient the large-scale application of these measures is and how they will affect the overall catchment behavior. Based on the WVSI-WRC model developed by USAL, the changes of the physical properties can be estimated. This small-scale analysis can be up-	• Physically based models using the HydroGeoSphere code are in active development for the Seeland, Lower Silesia and Tyvärnä case study sites, in collaboration with UPWr and OULU. Preliminary models have been generated. The final models are still to be created. • Necessary data and maps for physically based model generation have been collected and are being transferred to the WATERAGRI GeoDatabase. • Data assimilation routines for the physically based modelling code HydroGeoSphere are in active development. • Synthetic modelling evaluation of soil water retention solutions are ongoing (in collaboration with UPWr and USAL)

scaled to the catchment-scale by combining them with the physically-based models employed at sites selected for this type of modelling. Given that the physically-based models are based on the same parameters, the efficiency of the proposed soil water retention solutions can be tested across large spatial scales. A physical-based surface water-groundwater flow model built in HydroGeoSphere will be used to study surface and groundwater interaction at the Seeland case study site, including the impact of in-stream and field water retention measures on recharge, agricultural stream water retention with interaction with the riparian zone water retention/recession processes and soil water retention in subsurface drains.	

3.8.3 Data availability and data provision

Table 36: Data availability – Case study 7

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
1) Availability of data	
• Hydrological data is generally collected by UNINE and therefore available for sharing within the WATERAGRI project. Non-hydrological data are typically not freely available, because they belong to several different institutions which are conducting research and collecting data in the Seeland region. Therefore, data access and use policies have to be organized and dealt with case by case. • In addition to the data which is listed in Table 14-16, there is a new dataset which consists of high-resolution spatial maps of peat soil loss observed during the last decades. • The measurement sensors of UNINE will be included in an already existing online sensor network for maximum visibility. The online sensor network can be accessed on bewaesserungsnetz.ch.	• data collection and setup of online sensor network completed.
Data are measured and are available on request	•

2) Data that are planned to be measured • Groundwater levels and volumetric saturation of the soil: The specific case study fields were also chosen due to the existence of a relatively dense hydrological measurement network operated by UNINE. A large amount of data therefore already exists, and during the project the existing timeseries will be extended. Additional sensors for groundwater levels and volumetric saturation of the soil will be put in place in early 2021 and data become available soon thereafter. • Meteorological data: An additional meteorological station will be installed on the case study fields in early 2021 and data become available soon thereafter. • Crop logs: information on the types of crops on the case study sites will be recorded starting in early 2021l	• hydrological data collection and setup of online sensor network completed. Data available for storage in GeoDatabase • meteorological data available from nearby weather station • data on crop logs available from local farming association. Available for storage in GeoDatabase by the end of 2022.
No further installations planned l	

Table 37: Current status of data provided – Case study 7

Which data have been made available to be included in the database until date?	• hydrological data collection and setup of online sensor network completed. Data available for storage in GeoDatabase • meteorological data available from nearby weather station
Which data will be available to be included in the database within this year? (e.g., until end of September 2022)	• data on crop logs available from local farming association. Available for storage in GeoDatabase by the end of 2022.

3.8.4 Photo documentation

Figure 35 shows a screenshot of simulation results using the first version of the model.

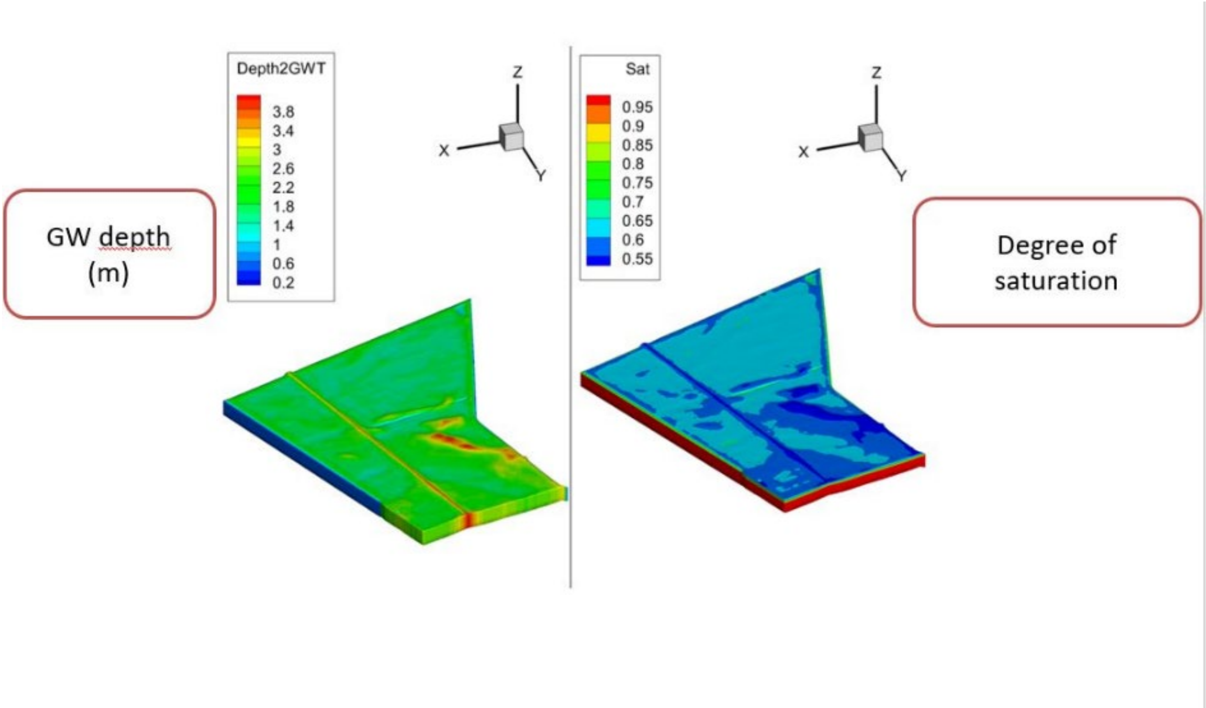


Figure 35: Screenshot of simulation results using the first version of the model: Left: Depth to groundwater, right: Soil saturation.

3.9 Case study 8 - Mistelbach/Obersiebenbrunn/Gleisdorf (Austria)

3.9.1 General overview

Table 38: General overview – Case study 8

Case study	WATERAGRI solutions	Partner involved
Austria I - Obersiebenbrunn 	Tracers (B7) Irrigation practices (B3)	Leader: BOKU Participants: BOKU
Austria II - Mistelbach 	Biochar for water retention (B6) Activated biochar (C2)	Leader: OULU Participants: ALCN and BOKU
Austria III - Gleisdorf 	Drainage systems (C4)	Leader: TBR Participants: ALCN and TBR

3.9.2 Updated implementation and research plans

Table 39: Updated implementation plan – Case study 8

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
Obersiebenbrunn: all sensors have been installed and monitoring is ongoing (related to other project at the same field site; in autumn 2020, soil depth profiles were sampled and water stable isotopes analysed in the pore water as well as soil	The implementation plan is finished

moisture content. Field survey for tracer analysis is finished.	
Mistelbach: ALCN is in charge of the implementation of the bio-inspired multi-layer drainage system combined with biochar and BOKU will assist. In autumn 2020 to spring 2021 a master thesis focuses on the determination of soil physical property and sorption analysis for different sediments to be used in the drainage system. In two students' projects, the dimensions of the drainage system will be investigated (Jan-Feb 2020) and the test system will be installed in the field in March 2021.	The master thesis and the students project have been conducted and yielded a basis for the design of the system. The bio-inspired multi-layer drainage system test setup including biochar has been implemented in Mistelbach from spring to early summer 2021. The system was hibernated in autumn 2021. The infrastructure to collect surface run-off will be reinstalled mid-April 2022 once the land is plated with the new crops. Monitoration will continue from April 2022 to September 2022.
Gleisdorf: The drainage system in Gleisdorf (Sytria) will be installed after evaluating the application of the drainage system in Mistelbach to identify potential for optimization. ALCN is in charge of the implementation in spring 2022, TBR will assist.	The drainage filter system is already planned based on the site-specific parameters and experiences from Mistelbach. Installed on 28 March 2022. Monitoring: April – September 2022.

Table 40: Updated research plan – Case study 8

Plan after M9 (January 2021, i.e., D5.1)	**Updated plan (M24, April 2022)**
Obersiebenbrunn: the tracer analysis is a space for time concept and therefore, the one-time sampling campaign has been finished in autumn 2020. The data will be analysed for the test site and further numerical experiments will be conducted to investigate for which climates and for which soils, the tracer methods can be applied for identifying water fluxes. It will be further used for assessing the impact of different irrigation practices.	The data have been analyzed, and a scientific manuscript is being prepared for the publication of the results. Data is being collected and prepared for the simulation study. The HYDRUS-1D software will be used for modelling the water fluxes in the unsaturated zone.
Mistelbach: the bio-inspired multi-layer drainage system combined with biochar will be installed in March 2021 and monitoring of the drainage system will be done by ALCN until autumn 2021. The monitoring includes measurement of nutrients from inflow and outflow of the drainage system to determine the nutrient retention capacity of the system. Measurements will be complemented by long-term monitoring of overland flow, nutrient concentrations in overland	The bio-inspired multi-layer drainage system combined with biochar was installed from Mai to June 2021 and monitoring of the drainage system was done by ALCN until September 2021. The monitoring includes measurement of nutrients from inflow and outflow of the drainage system to determine the nutrient retention capacity of the system. Due to challenges with sampling, the monitoring will be repeated in 2022.

flow and erosion from BOKU's long-term erosion plots at the same site.	
Gleisdorf: The drainage filter structure filled biochar will be installed in spring 2022 and monitoring of nutrient and water retention by the drainage system will be done by ALCN at least until autumn 2022 to generate knowledge about the system.	The drainage filter system is planned based on the site-specific parameters. The 3-D printed structure filled with reactive material (biochar) will be inserted into the subsurface drainage pipe. Monitoring plan includes measurements of outflow water volume, pH, nutrients (NO3-N, PO4-P, NH4-N)

3.9.3 Data availability and data provision

Table 41: Data availability – Case study 8

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
1) Availability of data	
Obersiebenbrunn: soil moisture measurements; use of tracers (B7) and modelling to assess water fluxes, water retention times and groundwater recharge rates (BOKU). Analysis of management practice and irrigation systems	Data collection for tracer studies finalised.
Mistelbach: measurements of overland flow, nutrient concentrations in overland flow and erosion rates (BOKU); analysis of geochemistry in drainage of the bio-inspired multi-layer drainage system (ALCN)	ALCN planned to analysed geochemistry (NO3-N, PO4-P, NH4-N) and in-and outflow of the bio-inspired multi-layer drainage system, moisture, and temperature in drainage system. Filter moisture and temperature has been measured at rainfall events with a follow-up time of 12 hours. No in-and outflow samples of the drainage system could be analysed in 2021 due to sampling challenges (lack of rainfall events, the experiment will be repeated in 2022. Monitoring 2022: • Re-optimization of the run-off collection system and drainage filter system – April 2022 • Attempt to conduct tracer tests (which were not conducted in 2021) • Inflow and outflow sampling and analyses for NO3-N and PO4-P, and NH4-N if needed. • Flow measurements (tipping bucket)

	• Moisture and temperature in drainage system at rainfall events.
Gleisdorf: Data of water quantity from drainage system. Nitrate and phosphate will be measured with consideration of field management (before harvesting, after fertilization etc.).	A survey on the original flow from the drainage system is being conducted in autumn/winter 2021 to serve as a base to dimension the drainage system. Monitoring 2022: • Inflow: pH, PO4, NO3-N, NH4-N • Effluent after each structure: pH, PO4-P, NO_3-N, NH_4-N. (NH_4-N only for certain periods related to manure applications or fertilizer type applied in the field).
2) Data that are planned to be measured	
• all in-situ measurements mentioned in Table 14-16 will be continued • additional tracer data have been taken at Obersiebenbrunn, which are depth profiles of water stable isotopes in pore water in 10cm-depth intervals from ground surface down to -90 cm.	No update

Table 42: Current status of data provided – Case study 8

Which data have been made available to be included in the database until date?	No representative nutrient data from Mistelbach is available now due to sampling challenges, a small set of filter moisture and temperature data is available. Small dataset on nitrate and phosphate concentration and quantity from drainage system is available.
Which data will be available to be included in the database within this year? (e.g., until end of September 2022)	All data mentioned in 5.8 for Mistelbach and Gleisdorf should be available until the end of September in raw form. (Monitoring also during September 2022), data can be available in the beginning of October 2022.

3.9.4 Photo documentation

3.9.4.1 Case study Austria I (Obersiebenbrunn)

Two sampling campaigns were conducted on the 28th and 29th of May 2020 to obtain soil samples from 16 soil profiles to cover all combinations of agricultural practices (i.e., four tillage variants, three irrigation systems and plots without irrigation). Profile samples were collected using a hand auger (Figure 32, left) and subsamples were taken every 10 cm and stored in Ziplog bags (Figure 32, right). Figure 31 shows orange sticks in the background where sensors to measure soil moisture are installed.

Figure 36: Sampling campaign in Obersiebenbrunn on the 28th of May 2020 for collecting samples for pore water isotope analysis.

Figure 37: Hand auger (left) used to take soil profile samples down to 90 cm depth; and disturbed soil samples collected in Ziploc® bags (right) from the subsamples taken every 10 cm.

Figure 38: Boom irrigation consisting of a hose reel boom with nozzles installed in the field.

3.9.4.2 Case study Austria II (Mistelbach)

After the literature research on nature-based solutions such as drainage filter systems, edge-of-field techniques and vegetated ditches, a design for two drainage filter systems was developed based on the Austrian standard for constructed wetlands (ÖNORM, 2009) (Figure 39).

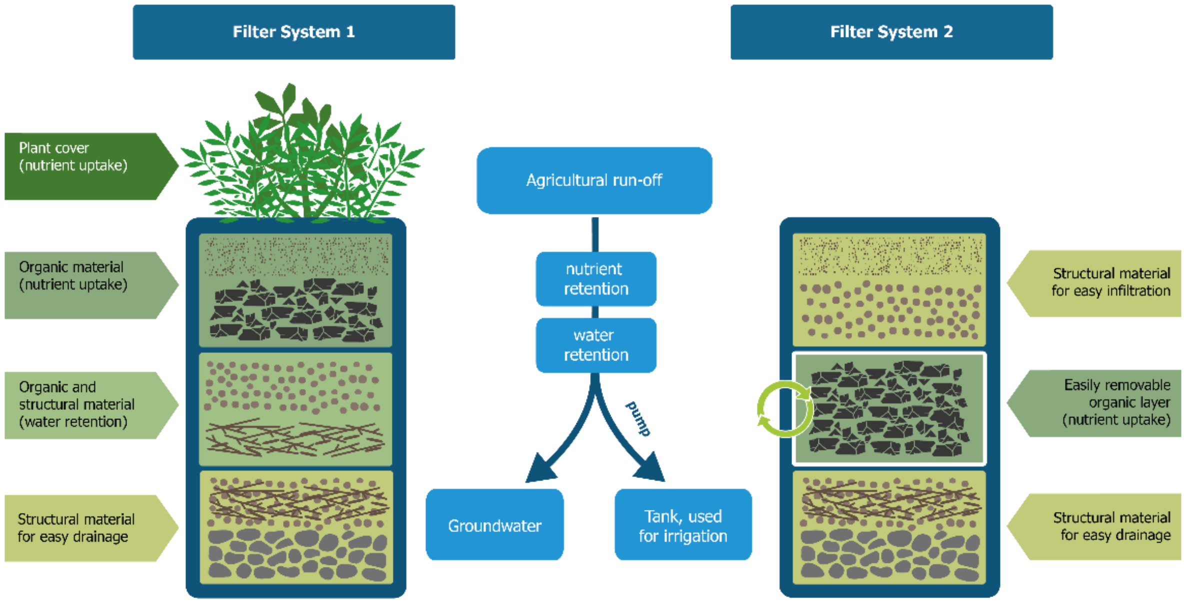


Figure 39. Drainage filter systems Mistelbach (*alchemia-nova, 2021*).

Figure 40. Drainage filter implementation at the Mistelbach demo-site (June 2021).

3.9.4.3 Case study Austria III (Gleisdorf)

The installation of the Gleisdorf demo-site is in planning, and currently the nutrient concentration in the drainage flow is assessed. A similar approach as in Mistelbach is adopted for the design, but it was re-iterated due to different flow conditions (drainage flow instead of overland-flow). The system will be installed by the end of March 2022 and the monitoring campaign will follow.

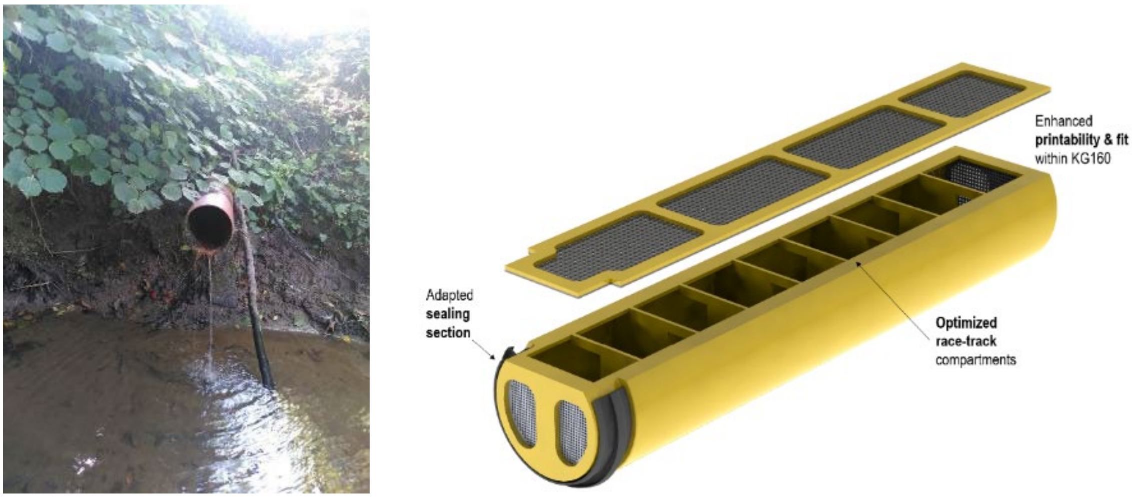


Figure 41 Gleisdorf subsurface drainage pipe (on the left), and the design of the structure which will be filled with filter material and will be inserted inside the drainage pipe (on the right).

3.10 Case study 9 - Bologna (Italy)

3.10.1 General overview

Table 43: General overview – Case study 9

Case study	WATERAGRI solutions	Partner involved
Italy 	Wetlands (B1+C1) Remote sensing pipeline (B2) Irrigation practices (B3+B4) Water retainer (B5) Dewaterability estimation test (B8) Bio-membranes (C3) Microfluidics (C4)	Leader: UNIBO and CER Participants: AGRICOLUS, BZN, USAL, VTT, VULTUS, CER and UNIBO

3.10.2 Updated implementation and research plans

Table 44: Updated implementation plan – Case study 9

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
Farm constructed wetlands for water retention (B1) - It is already an existing system. The monitoring has begun. The trials will last until the end of the Task 3.3.	The monitoring was finished and the final results were included in D3.2.
Remote sensing pipeline (B2) – Cooperation with VULTUS started. After some exchange of information satellite data analysis is starting for identified fields cropped in the years from 2018 till 2020. Further analysis and on purpose measurement are possible in 2021.	Cooperation with VULTUS is ongoing. After some exchange of information, satellite data analysis is starting for identified fields cropped in the years from 2018 till 2020. Further analysis and on purpose measurement are possible in the future period.
Irrigation management and agrometeorological monitoring solutions (B3) – The assimilation of vegetation information from high-resolution remote sensing products and spectral data for optimizing irrigation scheduling was forecast also for the CER experimental farm, however CER is not equipped with LIDAR. The data provided to assess the effectiveness of the VULTUS EO products will be made available also for B3 so	The assimilation of vegetation information from high-resolution remote sensing products and spectral data for optimizing irrigation scheduling was forecasted also for the CER experimental farm, however CER is not equipped with LIDAR. The data provided to assess the effectiveness of the VULTUS EO products have been made available also for B3 so that the information from satellite

that the information from satellite observation (VULTUS) should be assimilated into the irrigation management.	observation (VULTUS) should be assimilated into the irrigation management. Further data on next years' cultivated crops can be provided if needed by partners.
Precision irrigation system (B4) – During the irrigation season 2021 some crops/irrigation methods will be selected among those CER will carry out in the frame of other projects to be utilised as benchmark for the AGRICOLUS solution.	During the irrigation season of 2021 some crop data have been collected and IRRIFRAME model implemented to serve as benchmark for the AGRICOLUS solution.
Water retainer (B5) - The tests should start in May-June 2021 and will last until the end of the irrigation season.	Field trials have been carried out to test water retainer's capability for corn cultivations in Italy. Trials on soybean crops are planned to be repeated in 2022.
Biochar for water retention (B6) - The tests should begin by April 2021 together with the pilot plant C1.	The experimental plan was established. The pilot plant C1, that will also test B6, has been constructed and the tests should start in the Spring 2022.
Dewaterability estimation test (B8) – Theoretically it is feasible to assess soil water content in the range between saturation and field capacity using the DET instrument. Until now the test was not performed because the equipment needed has not been sent due to the COVID19 pandemics. The estimated beginning of the tests is spring/summer 2021	Tests to assess the capabilities of DET apparatus on agricultural soils have been carried out. If needed, additional trials can be carried out to further understand the procedures and interpretation of results.
Farm constructed wetlands for nutrient recovery (C1) - The pilot plant is being designed and should be operational for April 2021.	The pilot plant has been constructed and is currently being tested. It should be operational in the Spring 2022.
Membrane-based solution (C3) - Initial discussion with VTT were done and the solution will be combined with the pilot plant C1.	Regular discussion with VTT were done and the experimental plan was established. The solution C3 will be tested within the pilot plant C1.
Biochar adsorbents for nutrient uptake (C4) - The tests should begin by April 2021 together with the pilot plant C1.	The tests should begin in the Spring 2022 together with the pilot plant C1.

Table 45: Updated research plan – Case study 9

Plan after M9 (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
Farm constructed wetlands for water retention (B1) - Inflow, outflow and water level inside the system is being performed. Infiltration trials and groundwater level monitoring have also begun. The trials will last until the end of the Task 3.3.	Measurements of inflow, outflow and water level inside the system are being performed also after the submission of D3.2.
Remote sensing pipeline (B2) – CER has provided to VULTUS the geomatics reference of the experimental field and the list of the available measurements for each field in the period 2018-2020. VULTUS will assess its own product re-analysing past images/data from the Copernicus satellites. Further calibration/validation should be carried out using data collected in 2021.	CER has provided to VULTUS the geomatics reference of the experimental field and the list of the available measurements for each field in the period 2018-2020. Data have been organized in database format and provided to the partners. VULTUS will assess its own product re-analysing past images/data from the Copernicus satellites. If needed by VULTUS, further calibration/validation can be carried out using data collected in 2021
Irrigation management and agrometeorological monitoring solutions (B3) - No tests are foreseen at the moment. CER can share the information collected for other projects when relevant for the B3 solutions.	No changes.
Precision irrigation system (B4) – The AGRICOLUS product will be benchmarked against the IRRIFRAME model manage by CER, that has been calibrated and validated in the area. The two DSSs will be run in parallel during the season 2021 for some crops to be selected among those cropped in the CER experimental farm.	The AGRICOLUS product will be benchmarked against the IRRIFRAME model manage by CER, that has been calibrated and validated in the area. IRRIFRAME was run for ACQUACAMPUS's crops for the season 2021.
Water retainer (B5) - Irrigation season 2020 could not be used for the experimentation due to the project beginning date. Some initial analysis was performed, and the product is planned to be applied during the next irrigation season (May-June 2021).	Irrigation season 2020 could not be used for the experimentation due to the project beginning date. In 2020 initial analyses were performed and the product has been tested in the field in the 2021 irrigation season (May-September 2021).
Biochar for water retention (B6) - Biochar will be used as a substrate in constructed wetland pilot plant in order to assess its effect on water retention.	Biochar will be used as a substrate in constructed wetland pilot plant in order to assess its effect on water retention
Dewaterability estimation test (B8) – Lab test will be carried out with different soils in order to assess feasibility and reliability of the use of the DET instrument to measure the water content at	Lab test were carried out with different soils in order to assess feasibility and reliability of the use of the DET instrument to measure the water content at the lowest soil matrix

the lowest soil matrix potential. This information would be useful to better drive model's algorithms management of the soil water content into a wetted bulb or soil saturated layers, either after rainfall or irrigation.	potential. This information would be useful to better drive model's algorithms management of the soil water content into a wetted bulb or soil saturated layers, either after rainfall or irrigation.
Farm constructed wetlands for nutrient recovery (C1) - The pilot plant based on constructed wetlands will test different substrates and plant species to estimate their potential for removal and recovery of nutrients. The monitoring will include water, substrate and vegetation analysis.	No changes.
Membrane-based solution (C3) - Trials with different nutrient concentrations will be done in order to estimate the potential of the solution for nutrient removal and recovery. Initial discussion with VTT were done and the solution will be combined with the pilot plant (C1).	Trials with different nutrient concentrations will be done in order to estimate the potential of the solution for nutrient removal and recovery. In accordance with VTT, the solution will be combined with the pilot plant (C1).
Biochar adsorbents for nutrient uptake (C4) - Biochar will be used as a substrate in constructed wetland pilot plant in order to assess its nutrient concentration and a possibility to use it for nutrient recovery or increased removal.	No changes.

3.10.3 Data availability and data provision

Table 46: Data availability – Case study 9

Original plan (January 2021, i.e. D5.1)	**Updated plan (M24, April 2022)**
1) Availability of data	
The farm is carrying out several experiments not funded by the WATERAGRI project. However, some information/measurements can be shared with WATERAGRI as, i.e., measurement of soil moisture sensors, shallow water tables, plant growth and plant canopy; outcome from mathematical models and support systems to assess crop and soil water balance, data on fertilization and overall crop husbandry.; meteorological station data.	No changes.
2) Data that are planned to be measured	
-	

Table 47: Current status of data provided – Case study 9

Which data have been made available to be included in the database until date?	Field geometry with crops and Soil analysis data have been already provided.
Which data will be available to be included in the database within this year? (e.g., until end of September 2022)	Meteorological station data; crop and soil water balance, data on fertilization and overall crop husbandry.

3.10.4 Photo documentation

Figure 42 and Figure 43 show the pilot plant that will be used for testing the solutions WATERAGRI B6, C1, C3 and C4, and accumulation tank and control unit of the pilot plant, respectively, at case study 9.

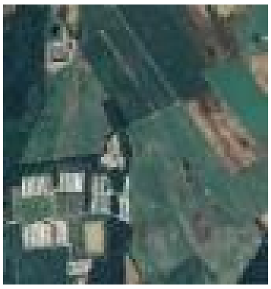
Figure 42: The pilot plant that will be used for testing the solutions B6, C1, C3 and C4.

Figure 43: The accumulation tank and control unit of the pilot plant.

3.11 Case study 10 - Nyírbátor (Hungary)

3.11.1 General overview

Table 48: General overview – Case study 10

Case study	WATERAGRI solutions	Partner involved
Hungary 	Physical modelling (A2) Irrigation practices (B3+B4) Water retainer (B5) Dewaterability estimation test (B8) Microfluidics (C4)	Leader: UNIDEB Participants: ULUND, FZJ, BZN, USAL and UNIDEB

3.11.2 Updated implementation and research plans

Table 49: Updated implementation plan – Case study 10

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
The implementation of A2, B3, B4, B5, B8, C5 WATERAGRI solutions will be tested in the following two vegetation periods, in 2021 and 2022.	
A model developer from UNIDEB is planned to work together remotely with FZJ from 2021 February/March till August/September contributing to the development physical based modelling with the model CLMParFlow based on soil survey and other sensor data (A2). In the second year, testing of the model is planned to be made. The aim of the implementation of this solution is to model water balance of the site, which can contribute to better irrigation scheduling (B3, B4).	A model developer from UNIDEB was planned to work together remotely with FZJ from 2021 February/March till August/September contributing to the development of the physically based CLM-ParFlow model and including information from the soil survey and other sensor data (A2). Due to Covid 19, this is delayed to 2022 spring, when a PhD student from UNIDEB starts at FZJ at the first week of April. In the second half of 2022, the testing of the model is planned. The model should provide improved estimates of the water balance at the site, which can contribute to better irrigation scheduling.
Implementation of B3 and B4 will start in 2021. In the first half of 2021 the AGRICOLUS B3 and B4 platform will be uploaded by basic field data,	In 2021, the Agricolus platform is tested. Basic field data are uploaded and used Agricolus in weather monitoring and crop monitoring. A

then a continuous implementation is planned till 2022 autumn. BZN will provide water retainer product for UNIDEB. UNIDEB will do preliminary researches on soil plant systems in 2021, small parcel testing is planned in 2022. DET (B8) is planned to be implemented in the fourth quarter of 2021 and in 2022. ULUND and USAL will provide DET and UNIDEB will test it with fermentation sludge, and possible utilization for soils amended by water retainer.	continuous implementation is planned till 2022 autumn. BZN provided water retainer product for UNIDEB. UNIDEB did preliminary researches on soil plant systems in 2021. Soil incubation experiment was made to study the effects of Water Retainer on soil conditions and nutrient status. Small pot experiment was made to study the effects of Water Retainer on soil physical, chemical and microbiological conditions and nutrient status in a soil-plant system. Field experiments were set up to study the effects of Water Retainer on soil physical conditions and furthermore nutrient uptake by the apple trees. Further plan is to continue small parcel testing in 2022.
UNIDEB will provide irrigation water and filtered fermentation sludge samples to support the development of the microfluidics technology (C5) in the next two vegetation periods. UNIDEB will be responsible for sample collection, Microfluidics for shipping the samples, and analysing them. Soil amended by water retainer will be tested by DET.	DET (B8) is started to be implemented in the fourth quarter of 2021 and continued in 2022. ULUND and USAL provide DET in September, and test papers at the end of October 2021 and UNIDEB tested it with fermentation sludge. UNIDEB will assess the possible utilization of DET for soils amended by water retainer. Additional work: In November 2021 and March 2022 filtered fermentation sludge and irrigation water samples were provided to Microfuidics for micronutrient and micro pollutant analyses.

Table 50: Updated research plan – Case study 10

Plan after M9 (January 2021, i.e., D5.1)	**Updated plan (M24, April 2022)**
At the test site soil survey has been made, and sample analyses are ongoing, and foreseen to be finished in February. DEM will also be prepared at that time based on LIDAR data. Then in 2021 contributing to Task 3.2. soil data will be used to analyse and model water and nutrient transport of soils, and with the use of meteorological data water balance of the site. In 2022-2023 the research also tries to explore the relationship among several soil parameters, such as soil	At the test site, soil survey and soil sample analyses were made in 2021. DEM was prepared at that time based on LIDAR data. Then in 2021 contributing to Task 3.2. soil data were used to analyse and model the water transport in soils, and with the use of meteorological data water balance of the site. In 2022-2023 the research also tries to explore the relationship among several soil parameters, such as soil density, SOM, pH,

density, SOM, pH, nutrients, micro-elements, hydraulic conductivity and matrix potential in five soil layers. Beside water balance modelling, soil moisture sensors will also be used for better irrigation scheduling in 2022.	nutrients, micro-elements, hydraulic conductivity, and matrix potential in five soil layers. Beside water balance modelling, soil moisture sensors were also tested in 2021 and will also be used for better irrigation scheduling in 2022.
The irrigation will be monitored by time series vegetation mapping for validation purposes. From one hand, satellite data and yield data partly from the case study site as well, will be used to develop a yield monitoring and prediction in 2021, which could also foster better nutrient and irrigation management in 2022. From other hand, the owner of the case study site is planning to survey the biomass with proximal sensors in 2021 and 2022, and UNIDEB is planning to do imaging vegetation surveys mostly in 2022 in order to test and validate the pivoting lateral moving variable rate sprinkler irrigation system.	The irrigation was monitored by time series vegetation mapping for validation purposes in 2021 and used as an input in task 3.2., D3.1. From one hand, satellite data and yield data from previous years partly from the case study site as well, were collected and used to develop a yield monitoring and prediction model in D3.1., which could also foster better nutrient and irrigation management. UNIDEB surveyed the maize plants with proximal sensors in 2020. UNIDEB did imaging vegetation surveys in 2021 by drones. Although only 3 surveys were done due to technical issues. In 2022 it is planned to continue survey in order to test the pivoting lateral moving variable rate sprinkler irrigation system by drone. Furthermore, the uniformity of irrigation was also tested in 2020 and 2022 investigating the accuracy of VRI of lateral moving irrigation system.
In 2021, the effect of water retainer product on soil water retention at modelled circumstances will be measured and analysed at laboratory scale at UNIDEB. Besides, pot experiment in controlled environment will also be implemented with certain test species to analyse the effect of water retainer on soil-water plant relations. In 2022 small scale field experiments will be set in order to measure the effect of water retainer on soil respiration and soil air permeability. Soil amended by water retainer will be tested by DET, to simulate the influence of the soil water retainer in the fourth quarter of 2021 and in 2022. DET will be tested by fermentation sludge as well, and the physical and chemical properties of the sludge will also be determined.	In 2021, the effect of water retainer product on soil water retention at modelled circumstances was measured and analysed at laboratory and field scale at UNIDEB. Besides, pot experiment in controlled environment was implemented with certain test species to analyse the effect of water retainer on soil-water plant relations. In 2022, small scale field experiments is planned to set in order to measure the effect of water retainer on soil respiration and soil air permeability. Soil amended by water retainer will be tested by DET, to simulate the influence of the soil water retainer in 2022. DET has already been tested by fermentation sludge, and the physical and chemical properties of the sludge was also determined.

3.11.3 Data availability and data provision

Table 51: Data availability – Case study 10

Original plan (January 2021, i.e., D5.1)	Updated plan (M24, April 2022)
1) Availability of data	
• Sensor data are collected by the owner of the case study site, data are provided only for WATERAGRI activities from data servers. • Spatial and field survey data are owned by UNIDEB, data is provided only for WATERAGRI activities.	• Sensor data were collected by the owner of the case study site, data are provided only for WATERAGRI activities from data servers. • Spatial and field survey data are owned by UNIDEB, data is provided only for WATERAGRI activities.
2) Data that are planned to be measured	
• Weather data is continuously measured by DAVIS weather station, T, Prcp, RH%, windspeed, wind direction, atmospheric pressure is measured to calculate ET in AGRICOLUS Irrigation management and agrometeorological monitoring solutions and in Precision irrigation system. • Soil moisture and soil temperature data is planned to be measured by sensors in the vegetation period of 2021 and 2022 for better adjusting of irrigation. • Spatial data will be provided in 2021, basic spatial data (site location, irrigated areas) will be utilized in AGRICOLUS platform. LIDAR, and LIDAR based DEM will be used for identification of spots with excess water risk. SOM and texture will be based on the survey data and will be used for mapping soil nutrient supply. • Soil survey has already done. Soil chemical, physical parameters, certain micronutrients in 5 layers (0-20, 20-40, 40-60, 60-80, 80-100 cm) and water retention data will be provided in 2021 and utilized in physical based modelling (A2). • Irrigation data and crop phenology is planned to be surveyed in maize in 2021 and 2022 in order to develop irrigation scheduling and implement B3 and B4. • Non-destructive vegetation survey (LAI) has already made in 2020, and this activity is planned to continue in 2021	• Weather data is continuously measured by DAVIS weather station, T, Prcp, RH%, windspeed, wind direction, atmospheric pressure is measured to calculate ET in AGRICOLUS Irrigation management and agrometeorological monitoring solutions and in Precision irrigation system. • Soil moisture and soil temperature data was measured by sensors in the vegetation period of 2021, and it is planned to measure in 2022 for better adjusting of irrigation. • Spatial data were provided in 2021, basic spatial data (site location, irrigated areas) was utilized in AGRICOLUS platform. LIDAR, and LIDAR based DEM was used for identification of spots with excess water risk and utilized in Task 3.2., D3.1. SOM and texture are based on the survey data and will be used for mapping soil nutrient supply. • Soil survey has already done. Soil chemical, physical parameters, certain micronutrients in 5 layers (0-20, 20-40, 40-60, 60-80, 80-100 cm) and water retention data were measured and then utilized in D3.1. The data are inputs for physical based modelling (A2), which is started to be implemented in April of 2022.

and 2022. Vegetation survey is planned to be supplemented by NDVI surveys mostly in 2022 to develop irrigation scheduling.	• Crop phenology were surveyed in maize in 2021 and planned in 2022 too in order to develop irrigation scheduling and implement B3 and B4. • Non-destructive vegetation survey (LAI) was made in 2020, in 2021 VULTUS API is used to collect LAI data in 2021. Vegetation survey is planned to be supplemented by NDVI surveys mostly in 2022 to develop irrigation scheduling.

Table 52: Current status of data provided – Case study 10

Which data have been made available to be included in the database until date?	Meteorological data (already linked with Agricolus), spatial data of the site, soil physical and chemical parameters with coordinates in excel, soil water retention data with coordinates in excel and LiDAR based DEM, maize BBCH data for 2020 and 2021. soil physical and chemical parameters and, soil water retention data are available as netCDF for physical based modelling.
Which data will be available to be included in the database within this year? (e.g., until end of September 2022)	Soil moisture data, maize BBCH data for 2022, and if required raster maps based on soil physical and chemical parameters and, soil water retention data

3.11.4 Photo documentation

The following figures show work carried out at case study 10.

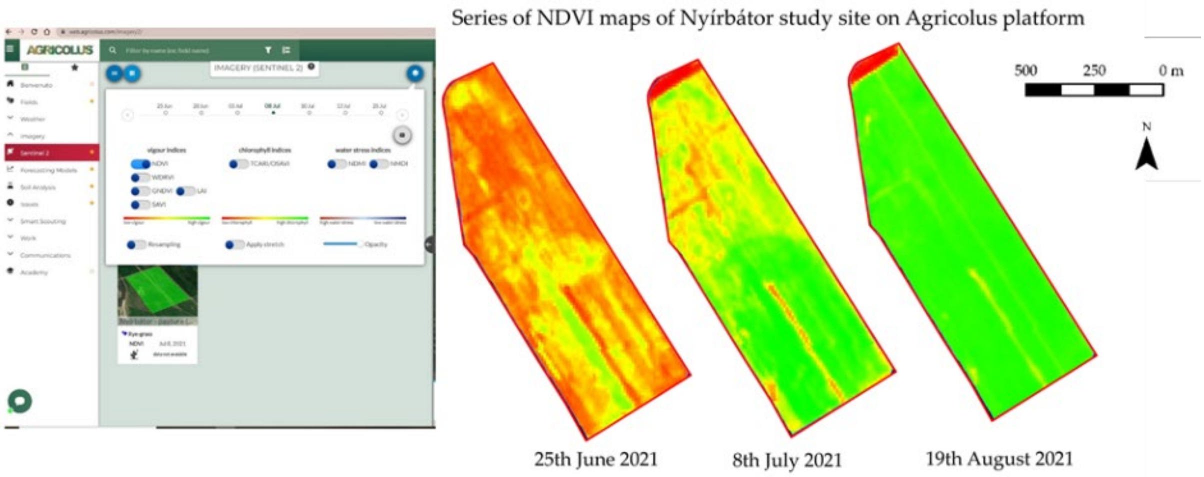


Figure 44: Implementation of Irrigation management and agrometeorological monitoring solutions using Agriculos platform based on uploaded field data at case study 10 (B3-4)

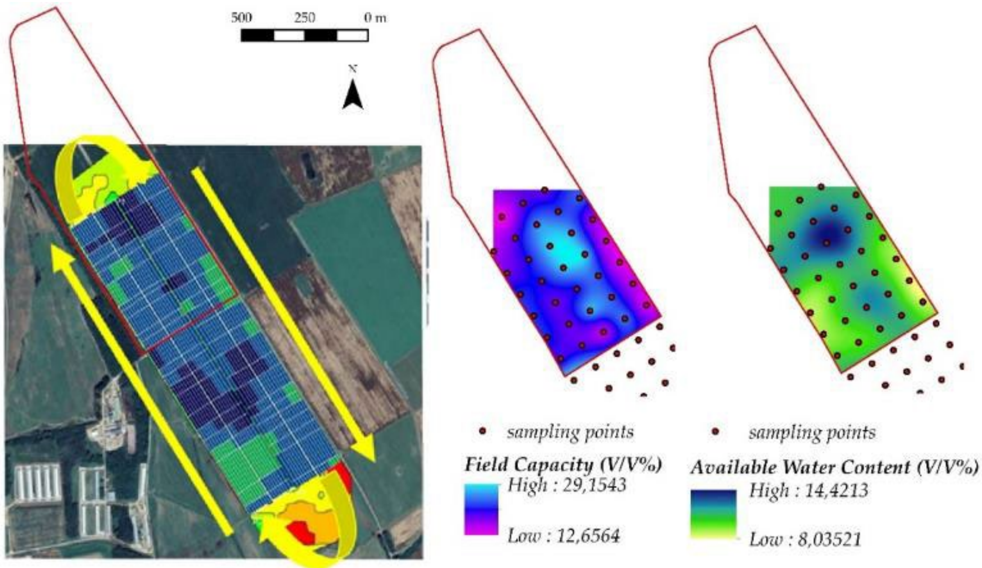


Figure 45: Development of precision irrigation system based on soil survey data at case study site 10. (First image is the prescription map for VRI)

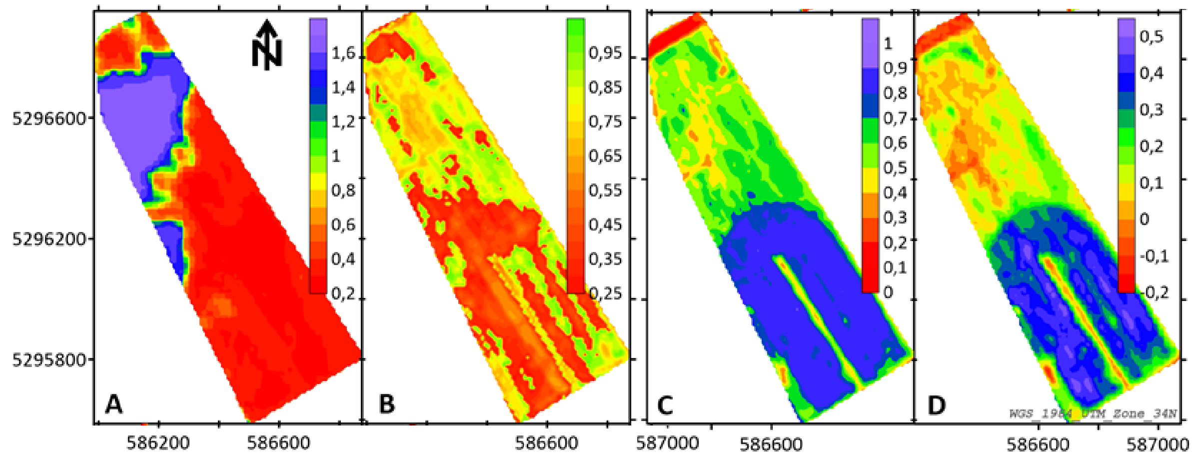


Figure 46: Implementation of user-friendly remote sensing solution to get timely information on the vegetation status in 2021 contributing to D3.1. at case study 10 (B2) LAI data on 8th June (A), NDRE data on the 25th of June (B), NDVI data on 13th July (C), NDWI data on 13th July

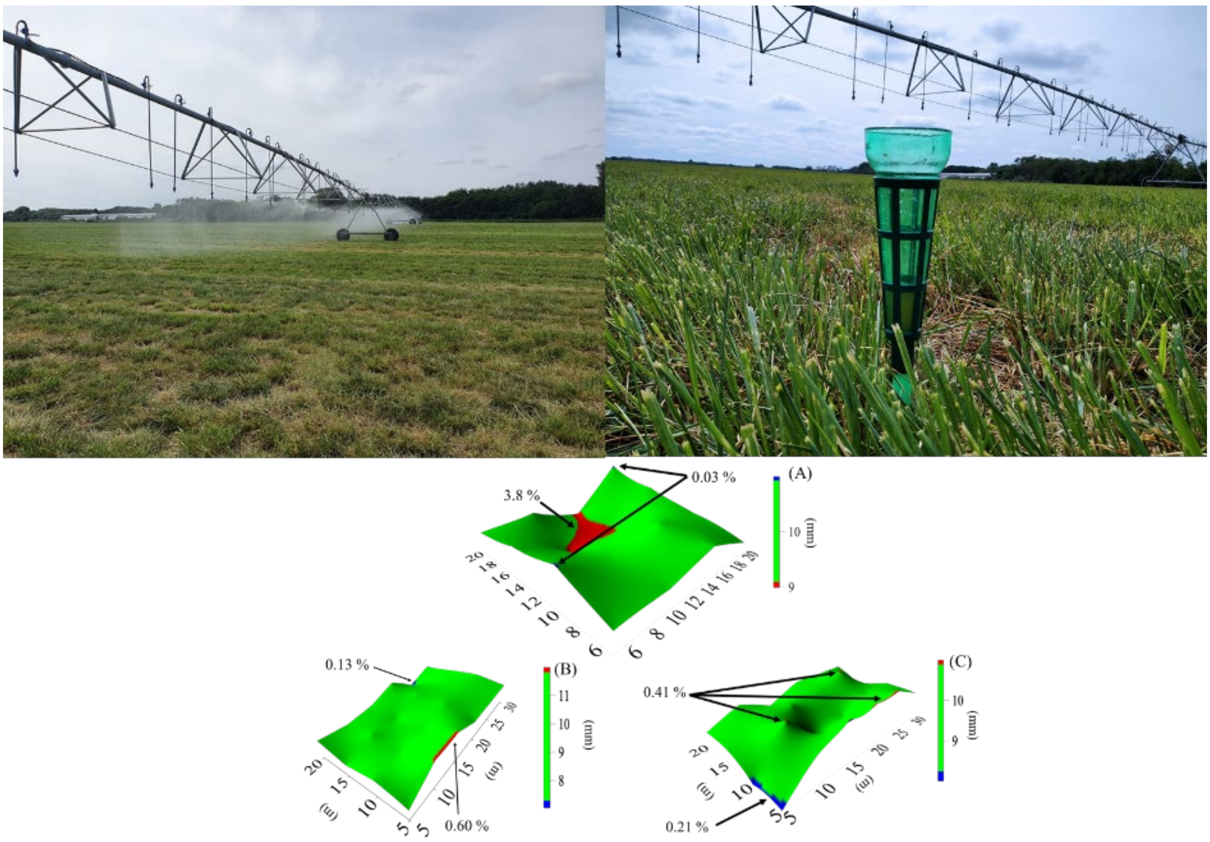
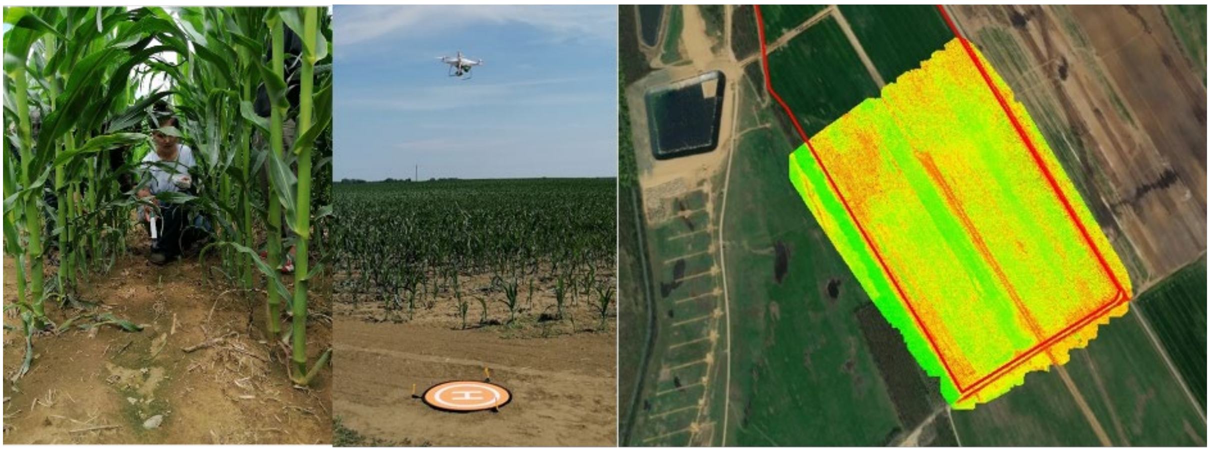
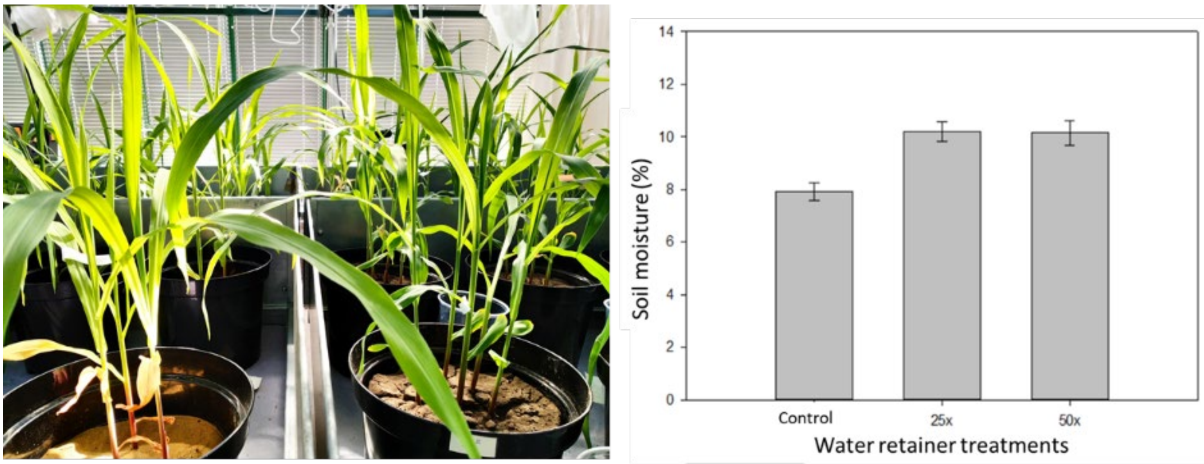


Figure 47: Distribution of under (blue)- and over-irrigated (red) area in the first (A), second (B) and third (C) measurements at case study 10. The distribution was measured based on survey using grids of chambers presented in this figure (B3-4)



A B C

Figure 48: LAI measurements (A) in 2020 and drone survey (B) and NDVI map results (C) in 2021 at case study 10 LAI was sent to VULTUS to utilize it to improve remote sensing pipeline (B2)



A B

Figure 49: Testing water retainer product in soil-plant system (A) and preliminary results (B) at case study 10 (B5)

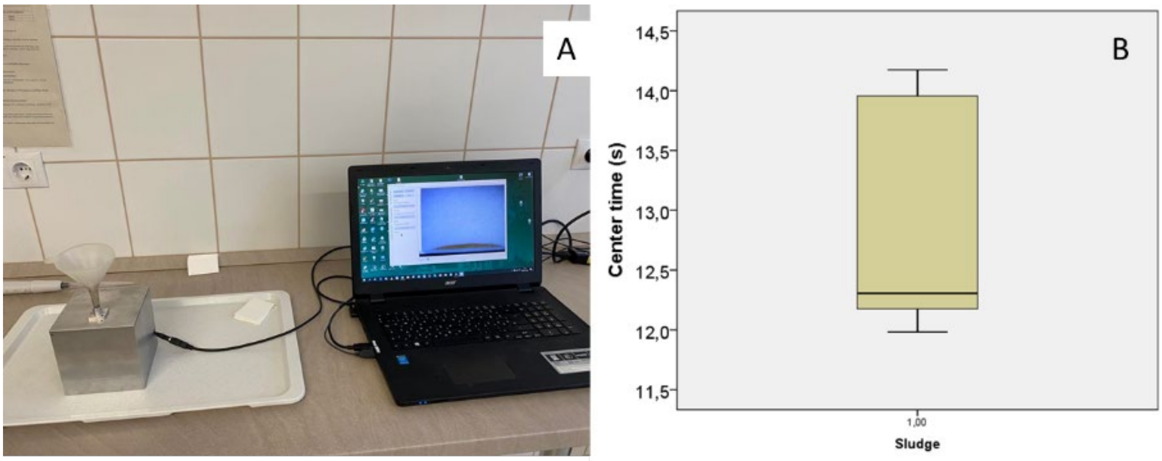


Figure 50: Testing of DET for fermentation sludge and preliminary results at case study 10 (B8) Measuring of diluted fermentation sludge used for irrigation (A), DET results of sludge

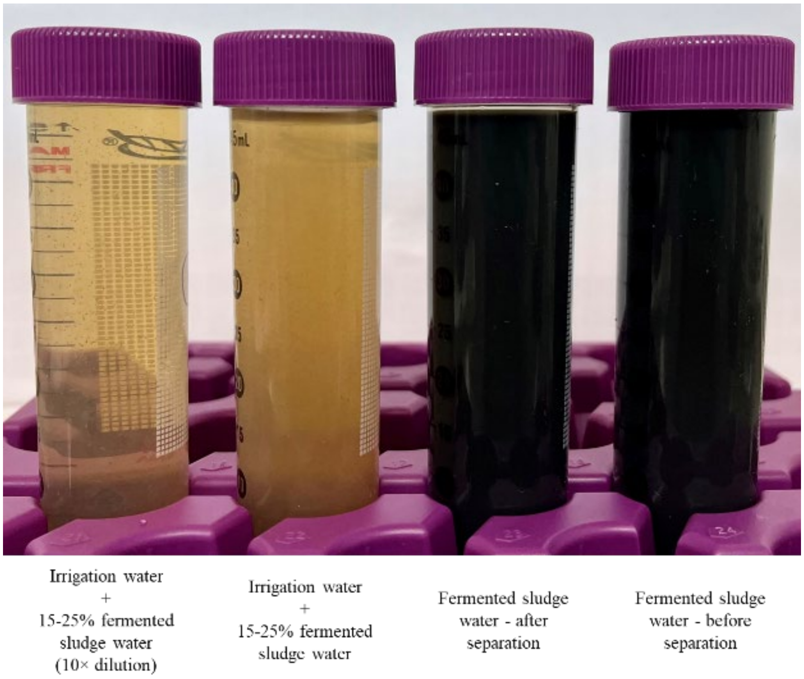


Figure 51: Filtered sludge samples sent to Microfluidics at case study 10 (C5)

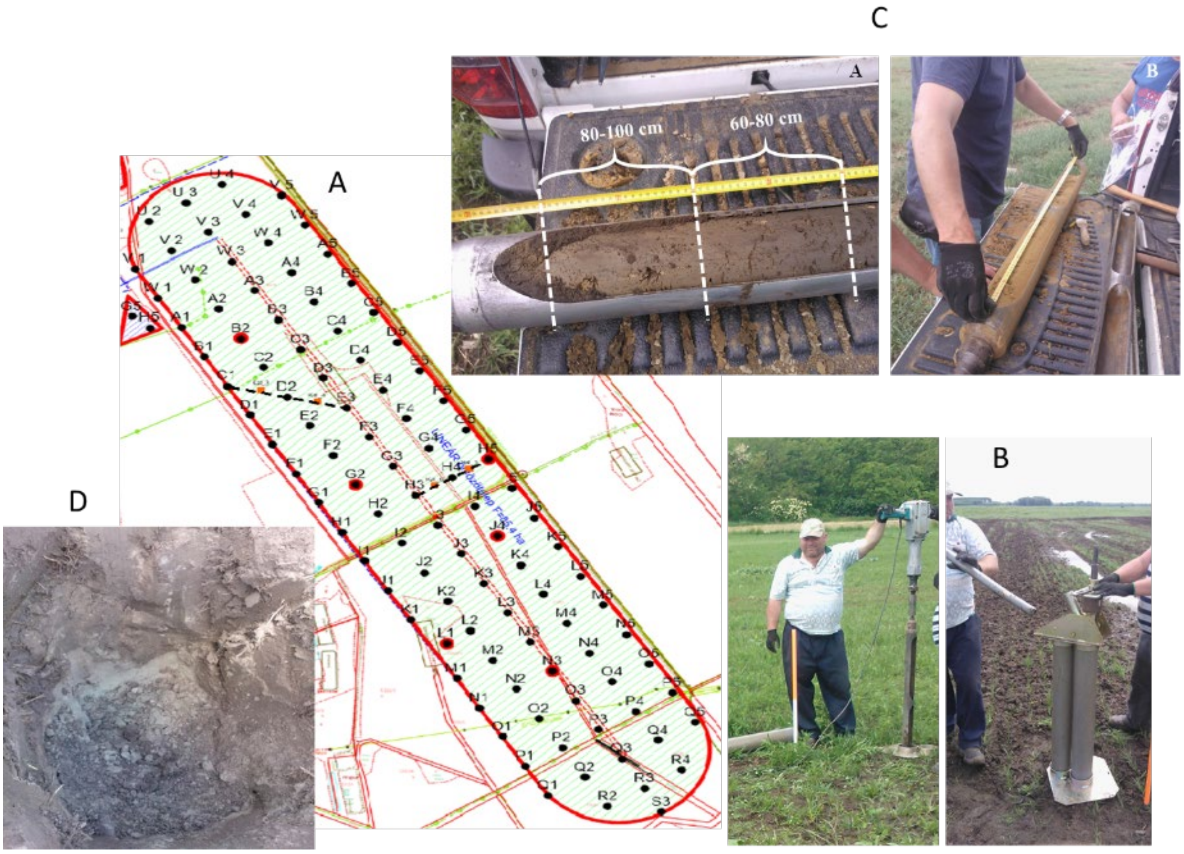


Figure 52: Soil sampling as an input for physical based modelling (A2) at case study site 10. Sampling strategy (A), sampling by Makita hammer (B), samples (C), aleurite layer at the site (D)

4 Summary

Deliverable D5.2 "WATERAGRI Solution Test Findings" builds upon the information presented in Deliverable D5.1 "Description of Case Study Sites" and provides information on the WATERAGRI case study sites. For each site the following information is provided:

- A short general description of the site including the WATERAGRI solutions at the site,
- The updated implementation and research plan,
- Updated information on data availability and data provision, and
- A photo documentation on implemented WATERAGRI solutions.

Table 53 provides the overview on which WATERAGRI solutions are tested at which case studies site.

In general, work at all case study sites is progressing well. There have been some delays due to the pandemic. At some sites, experiments have to be repeated due to unfavourable weather conditions during the last season.

In the final deliverable of WP5, i.e., Deliverable D5.3 "Data Collected from Case Study Sites", the main findings from testing WATERAGRI solutions at the Case Study sites will be presented. Evaluation of specific results will be presented in the respective deliverables in other WPs (links to these deliverables will be provided in Deliverable D5.3). Deliverable D5.3 is linked to Milestone M12 (WATERAGRI Solutions Tested).

Table 53: Summary on WATERAGRI Case Study sites and WATERAGRI Solutions (solutions A1 and A3-A6 will developed at and for all sites).

	WATERAGRI Solutions	**Physical modelling**	**Wetlands**	**Remote sensing pipeline**	**Irrigation management and agrometeorological**	**Precision irrigation system**	**Water retainer concept**	**Biochar for water retention**	**Tracer methods**	**Dewaterability estimation test**	**Farm wetlands**	**Drainage systems**	**Membrane**	**activated biochar**	**Microfluidics**
		FZJ	**ULUND**	**VULTUS**	**AGRI-COLUS**	**AGRI-COLUS**	**BZN**	**ALCN**	**BOKU**	**USAL**	**ULUND**	**ALCN**	**VIT**	**ALCN**	**EDEN**
WATERAGRI Case Study sites		**A2**	**B1**	**B2**	**B3**	**B4**	**B5**	**B6**	**B7**	**B8**	**C1**	**C2**	**C3**	**C4**	**C5**
Finland I	**OULU**	X		X	X								X		
Finland II	**OULU**	X							X				X		
Sweden	**GN**		X				X			X	X				
France	**INRA**						X								X
Germany	**FZJ**	X		X											X
Poland	**UPWr**			X	X	X	X			X					
Switzerland	**UNINE**	X			X	X									
Austria	**BOKU**				X			X	X			X		X	
Italy	**UNIBO**		X	X	X	X	X			X	X		X		X
Hungary	**UNIDEB**	X			X	X	X			X					X