WATERAGRI

D 1.2 Stakeholder Training Material

04/2023

WP 1 Farming Community Engagement

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Abstract:	This deliverable aims to provide stakeholders with the teaching material for all WATERAGRI solutions. The stakeholder training material can provide complete information and knowledge for all stakeholder groups about WATERAGRI solutions for water retention and nutrient recovery. This deliverable represents a complex training material supplemented with PowerPoint slides to develop practical knowledge. The training material provides updated information for farmers facing drought and other challenges concerning climate change and different types of farming.

Document Revision History			
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RE	Restricted to a group specified by the consortium (including the EC Services)	-

WATERAGRI Consortium			
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Table of Contents

List of Tables

List of Figures

List of Abbreviations and Acronyms	
CDI	Combined Drought Indicator
DET	Dewaterability Estimation Test
SPI	Standardized Precipitation Index

1. Introduction

WATERAGRI uniquely integrates the most updated solutions and technologies on water retention and nutrient recycling. It contributes to a deep understanding of hydrological processes with sustainable use of water resources.

The stakeholder training material provides opportunities and knowledge not only for farmers but also for the most relevant stakeholder groups, including farmer advisory organizations, on how to improve the sustainability and productivity of farming to water-efficient use in agricultural sectors are arable land, orchard, vineyard, grassland. WATERAGRI solutions have become updated and available for other sectors such as biogas plants, aquaculture, animal husbandry, and wastewater treatment to improve their competitiveness in water management: retention, reuse, and nutrient recovery.

Tackling the quantity and quality of water in small agricultural catchments has been overlooked in Europe. Hydrological processes and interactions have not been analysed in detail. Natural water retention at a small scale has not been addressed properly.

Equally, the local impact of climate change or/and changes in local micro-climate has not been analysed in an integrated way with other challenges of small-scale catchments. A sufficient water supply for sustainable crop production might become more important in the coming years. At the same time, several underutilised new water management techniques (natural/small water retention, nutrients recovery from streams, etc.) should be re-introduced after sufficient testing into agricultural management for the benefit of farmers, local communities and the environment.

The stakeholder training will be implemented with face-to-face or virtual half-day meetings that will be supplemented with an on-site facultative program, including a demonstration of selected WATERAGRI solutions. The stakeholder training is focused on water retention and nutrient recovery technologies and solutions developed as part of the WATERAGRI project. There are several reasons why it is important to teach and train on this topic stakeholders such as farmers, farm advisors, agricultural and civil engineers, the public, policymakers and researchers.

Drought in Europe is considered a crucial problem that causes economic damage due to a persistent lack of precipitation combined with a sequence of heat waves. In view of the excess of water, extreme precipitation and flood events can cause economic damages to crop farming and settlement infrastructure; in some cases, 200-250 mm of rain was recorded within 24 hours in 2022. Nutrient recovery plays a decisive role in drainage water, agricultural wastewater, pond aquaculture effluent, biogas digestate treatment and utilisation to avoid surface water pollution with readily available carbon, nitrogen, phosphorus, and toxic elements.

WATERAGRI solutions for nutrient recovery produce additives and inputs for fertiliser development. The continuous increase in inorganic fertiliser prices provides an opportunity to replace import products from non-EU members, for example, phosphate rock materials. WATERAGRI provides solutions for all relevant types of farming and agro-industrial plants that operate across Europe, in the Boreal, Continental, and Pannonian geographical zones, such as crop farming, animal husbandry, horticulture, mushroom cultivation, pond aquaculture, agricultural biogas farms, food and crop-processing industry, growing substrate production.

Based on the above mentioned, the goal of this deliverable is to provide a knowledge transfer training material for local farmers describing the activities and solutions in relation to WATERAGRI that is addressing the issue of reduction of conventional water resources and utilization of alternative water sources for irrigation, nature-based solutions for nutrient recovery to adapt to climate change. The training material will provide improved knowledge for the farming community about the information and modelling processes that will be required for water-energy safe and less nutrient-polluting agricultural practices.

2. Excess and shortage of water in Europe

Climate change is leading to more extreme weather conditions, with increased drought, flooding and inland excess water damage to agriculture affecting food security.

Europe is considered the most important food exporter in the world, which refers to cereal production. Agricultural water management problems transcend national borders, so an agricultural geopolitical assessment of risks is warranted to inform more coherent cross-border integrated territorial water management decision-making. In addition, agricultural production is the largest water-using economic activity in the world, so optimising it in space and time is a key area for climate adaptation. Soil water content plays a prominent role in the yield harvested.

A significant decrease in soil moisture content for 45 % of croplands across Europe during the last decades was reported. The most sensitive period, from April to September, is highly affected by available soil water content (Pinkeet al., 2022).

Shortage of water in Europe

Temperatures in Europe have increased at more than twice the global average over the past 30 years – the highest of any continent in the world. As the warming trend continues, exceptional heat, wildfires, floods and other climate change impacts will affect society, economies and ecosystems (WMO, 2021). For Europe, the damage caused by droughts between 1950 and 2014 has been estimated to be 621 million EUR on average per event (Guha-Sapir et al., 2015). To date, 11% of the European population and 17% of the area of the EU have been affected by water scarcity (Zink et al., 2016). From 2006-2010, on average, 15% of the EU territory and 17% of the EU population have been affected yearly by meteorological droughts. In the 1990s and 2000s, the drought hotspots were the Mediterranean and Carpathian regions (EEA, 2017). Recent droughts in Central Europe are 2003, 2015, 2018, 2019 and 2022. The summer droughts of 2003 and 2019 had a larger spatial extent throughout Central Europe than the 2015 and 2018 events. While the 2018 event was centred in southwest Germany and neighbouring countries, the drought in 2019 affected mostly parts of Poland, eastern Germany, and the Czech Republic until July before spreading westward in August. Overall, in 2019 the drought affected all of Central Europe, while the eastern part of Central Europe was less affected in 2018. The drought of 2015 lasted the longest, but the maximum water deficit was only about half the maximum deficit of 2019 (Boergens et al., 2020). In recent years the number of heat waves and drought conditions has increased in Europe (Ercinet al., 2021). This hydroclimatic anomaly is probably caused by anthropogenic warming and associated changes in the position of the summer jet stream (Büntgen et al., 2021). These trends have a high impact on crop rotation in arable land farming that can generate a decreased share of corn and sunflower on marginal agricultural sites based on opinions expressed in the GRANOFARM workshop held in Kecskemét on December 2, 2022.

In terms of the drought, the year 2022 is considered the worst of the last 500 years (BBC, 2022). As previously investigated, climate change and drought significantly affect Europe's Boreal and Temperate zones, and forest disturbances are expected to increase.

For the Standardized Precipitation Index, the most affected states during 2022 in negative anomalies were: Portugal; Spain; southern France; central Italy; Switzerland; southern Germany, Ukraine, Slovakia, Hungary, Romania, Moldova; Balkans.

Soil Moisture Anomalies were determined negative across Europe due to a lack of precipitation and a high number of heat waves that occurred.

Heat waves increase evapotranspiration, which can generate a significant loss in yield. Several periods of heat waves lasting 10-13 days were observed in the Iberian Peninsula and Italy in 2022.

In 2022 historic drought and successive heatwaves occurred in Europe that negatively affected maize development during crucial summer growth stages Figure 1). Based on the Combined Drought Indicator (CDI), including the first ten days of August 2022, points to 47% of Europe is in warning conditions and 17% in alert conditions (Fig. 1). Soil moisture and vegetation stress are both severely affected. Drought hazard has been increasing, especially in: Italy, Spain, Portugal, France, Germany, the Netherlands, Belgium, Luxembourg, Romania, Hungary, northern Serbia, Ukraine, Moldova, Ireland and the United Kingdom. The regions most affected by the negative precipitation anomalies in the three months ending on the 10th of August 2022 are central and southern Portugal; Spain; southern France; central Italy; Switzerland; southern Germany; a wide area across Ukraine, Slovakia, Hungary, Romania, Moldova; large areas in the western Balkans (Toreti et al., 2022).

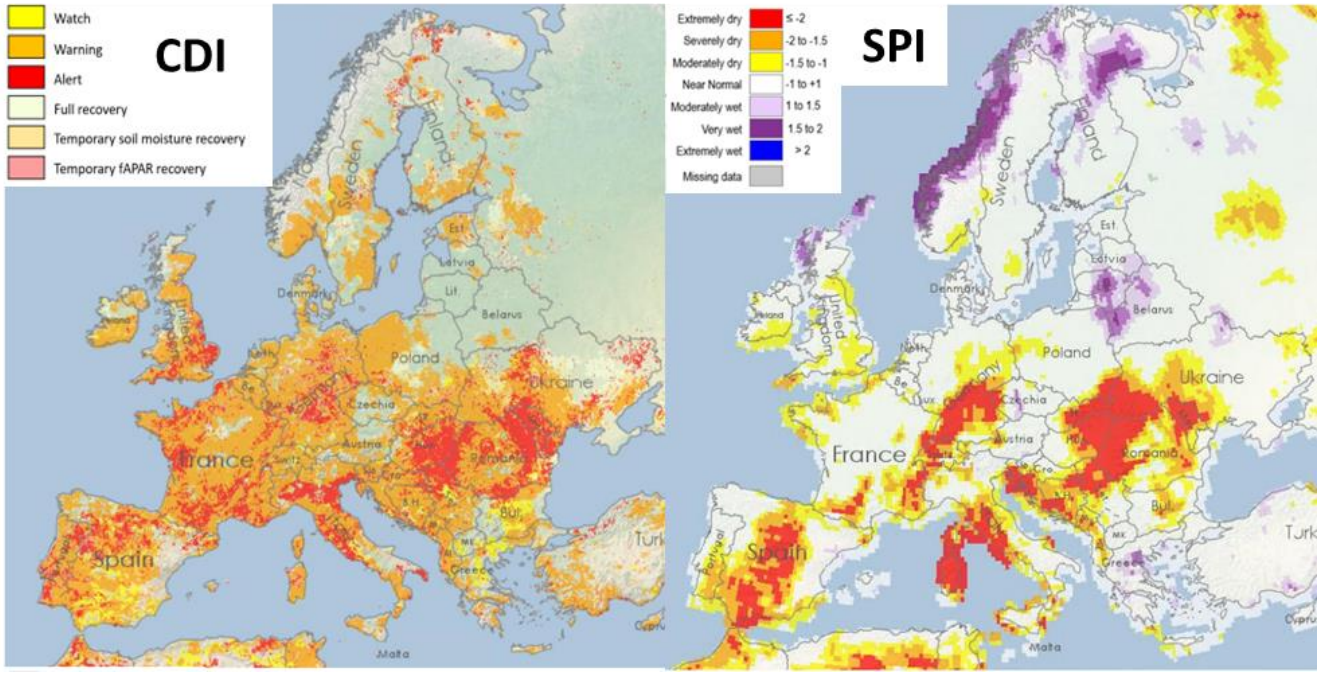

Figure 1: Combined Drought Indicator (CDI v.2.1) – beginning of August 2022 and Standardized Precipitation Index SPI-3, three months ending 10th of August 2022. (Toreti et al., 2022)

Due to situation in drought reported last year, Hungary is considered a net importer of crops. For example, maize production did not reach 2.4 million tonnes instead of the average of 6.5-9.3 million t (Szedlák, 2022).

In Hungary, the Interfluvial Region is covered by sandy soil. The corn lands were completely dried up till August 2022, which means only silage-based production was realised as 23 bales for 2,2 hectares on loamy sand soil. For arable lands without irrigation, the soil moisture content in the 0-20 cm top layer decreased to 14-22 % in August, which contributed to completely destroying corn, and sunflower lands on fertile soil loamy and chernozem soils as well. In contrast, this January, soil moisture content reached 100 % in 0-20 and 50-100 cm layers, which caused a surplus of surface water in some catchment zones.

Excess of water in Europe

Agriculture accounts for the largest use of water in Europe. Around 9 % of Europe's total farmland is irrigated (EEA, 2021). Due to drought events and heat waves, more farmlands need to be irrigated to maintain productivity in crop farming. During the last decades, drainage was the most important solution to treat excess surface water; however, water retention is currently considered one of the most significant solutions that provide an opportunity to mitigate economic damages and retain more water for irrigation and agricultural use. The extreme meteorological events: storms, hailstorms, heavy rainfall, and flash floods caused economic damages across Europe in recent decades, as well as in 2022.
Storm Franklin caused severe flooding in the UK from 20 February 2022, prompting evacuations in England and Wales. Franklin followed Dudley and Eunice, that was responsible for 1.4 million homes that were left (www.efas.eu).

During the 2022 summer, extreme rainfall was recorded in Valencia in May that caused flooding across the city. The total rain analysed was 232 mm, while the average annual precipitation is around 475 mm.

Severe weather events that occurred in France in May 2022 were storms, floods, and heavy rain with hailstorms. In June, 50,000 lightning strikes were reported due to wind speeds over 100 km/h during heavy storm activity.

In Greece, extreme rain was observed in October that caused flood damage. In Stitia, 239 mm of rain was reported in 24 hours.

A flash flood event was reported in Lisbon in December. Buildings, including a hospital, were damaged, roads were cut, and vehicular tunnels closed.

The effects of drought and excess surface water influence not only agriculture and crop production but also all living organisms, including domesticated and wild species of plants and animals, but also humans themselves. This means that damage is caused to not only cultivated but also non-cultivated areas and areas under conservation protection, as well as to human society. Moreover, in recent times it has become clear that the pace of change in the natural and social environment is accelerating, while at the same time, the impacts of change are becoming increasingly widespread, complex and permanent. Consequently, there is a need to develop tools and measures that can be deployed to counter the adverse effects of drought and excess of surface water and that can influence the preparedness of society as a whole, politics, economics, the ecological environment, justice and ethics, as well as individual and community behaviour, for the sustainable development of society.

Figure 3: Excess of water in Hungary, (January 22, 2023), Drought in Hungary, corn plantation (July 15, 2022)

Farmers' reflection on drought conditions in 2022 – potential solutions

AGROGEO organized the GRANOFARM workshop in Kecskemét (Hungary) on December 2, 2022, to obtain valuable information from farmers about their opinion on drought and how to adapt to drought conditions. The forum also provided good practice in communicating WATERAGRI solutions for water retention and nutrient recovery at the farm level. GRANOFARM is a Hungarian EIP AGRI group bringing together farmers, farm advisers, and researchers to develop organic fertilization technology for precision cropping.

Questions and responses were collected during this workshop:

(A) Answers:

- How did drought affect agricultural production in 2022?
- Which kind of solutions are available in practice to retain water in sandy soil?
- Do you use organic fertilizers to replace inorganic fertilizers to maintain soil fertility?
- Which kind of tilling and soil cultivation methods are in practice to avoid soil compaction?
- Do you know drip irrigation technology in corn or valuable crop farming?
- Do you know locally or regionally available biomass-based fertilizers and certified products?
- How do you see the current state of the groundwater level in the Kiskunság region?
- Is it a growing concern for deflation currently?

(R) Responses:

- Drought was considered the most relevant issue during this meeting that caused severe yield loss for corn and sunflower in Bács-Kiskun County in Hungary.
- Most farmers use reduced tillage for arable crops that can be supplemented with combined cultivation of main and cover crops.
- In integrated pest and fertilizer management, farmers hold 5 hectares on average and apply animal manure or organic fertilizer 1 time for a 3-year period.
- In organic farming, most farmers use cover crops that could be more appropriate than deep loosening to improve soil water and nutrient management.
- Due to the frequency of drought events realized during the last 10 years, new drip irrigation technologies are available on the market, especially for arable crops.

The GRANOFARM EIP AGRI group involved a Water Retainer product in the field test to investigate the effect on soil water transport and crop vegetation in 2022.

- Farmers applying integrated pest and nutrient management can utilize locally available organic fertilizers: composts, and soil conditioning products with certification.
- Decreasing groundwater level in the Great Plain in the Kiskunság region in Hungary.
- Lack of surface cover on arable lands contributes to soil degradation during winter or early spring,

3. WATERAGRI project from the perspective of farmers

WATERAGRI is an H2020 Research & Innovation project worth EURO 7,000,000, starting in May 2020 and lasting four years. The project aims to re-introduce and enhance sustainable water retention and nutrient recycling solutions to enable agricultural production that can sustain growing populations and cope with current and future climate change challenges. To achieve these ambitious aims, WATERAGRI will further develop traditional drainage and irrigation solutions and re-introduce nature-based solutions such as integrated constructed wetlands, bio-inspired drainage systems and sustainable flood retention basins in the agricultural landscape, leading to better retention of both water and nutrients. WATERAGRI will evaluate specific water and nutrient retention needs with the farming community, develop a set of affordable and easy-to-implement technologies, test them in the field and deploy a sound business framework for their effective use by the framing community.

The WATERAGRI consortium consists of 23 partners from 12 European countries who teamed up under Lund University's (Sweden) leadership. Among the partners, there are 4 and 3 world-leading water retention and nutrient capture experts, respectively, from prominent European water and soil research institutions and centres and international experts on stakeholder engagement and communication. The WATERAGRI project started in May 2020 and will last four years.

The project activities include 10 important case studies with a focus on specific biogeographical regions of Europe: Boreal Zone (Finland and parts of Sweden), Continental Zone (Poland and parts of Sweden, France, Germany, Switzerland, Austria and Italy) and Pannonian Zone (mainly Hungary). Here, the economically sustainable WATERAGRI technologies will be tested and deployed for different land use and crop types, from grass production and pasture to organic and conventional (fruit) farming. The test field sizes will vary from 1 ha up to 1000 ha.

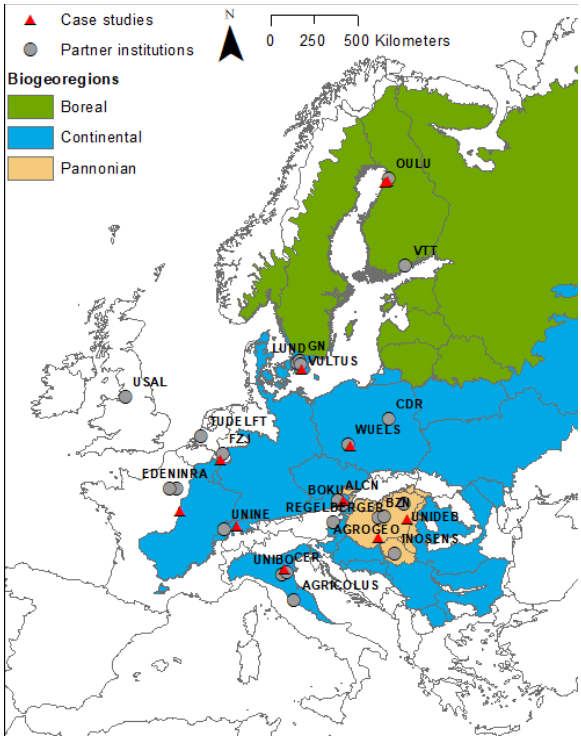

Figure 2: WATERAGRI covers the most relevant bio-geo-regions in Europe.

For more information about the project and its solutions, please visit the project website (https://WATERAGRI.eu/).

Target audience:

All stakeholder groups: farmers, farm managers, farm advisers, agricultural and civil engineers, the public sector, and researchers.

The most affected farm types for WATERAGRI solutions:

AGROGEO organized the GRANOFARM in Kecskemét on December 2, 2022, when the most relevant farm types were identified at the regional level for the potential use of WATERAGRI solutions: arable land farming, horticultural crop production, aquaculture, wastewater generates from food processing industry, animal husbandry, utilization of agricultural biogas digestate originates from small and medium-sized plants, oyster mushroom substrate production.

Linking to the European Green Deal strategy:

WATERAGRI is based on circular economy aspects, which means sustainable water recycling is suitable for agricultural production using farm-constructed wetland and nutrient recovery solutions. WATERAGRI provides solutions to recover mostly dissolved carbon compounds, nitrogen, phosphorus, toxic elements, and organic pollutants from water bodies.

WATERAGRI for the European Innovation Partnership (EIP-AGRI):

Due to the early engagement of stakeholders are as farmers, farm advisers, farming consultants, public bodies, and policymakers, WATERAGRI provides the most updated solutions for farmers to improve the productivity and sustainability of crop farming and agricultural production in the most sensitive sectors.

WATERAGRI for smart and precision agriculture:

The emergence of information and communication technologies contributes to increasing the efficiency of crop farming and more sustainable use of inputs. Novel technologies include wireless sensor networks, the Internet of Things, artificial intelligence, machine and deep learning, and computing technologies.

Remote sensing is considered a complex tool to improve the efficiency and sustainability of crop farming based on the currently applied mobile technologies such as:

- Drone (UAV): high-level mobility, easy to transport, complex use: monitoring + plant protection, average implementation cost, good reliability and manoeuvrability, limited flight options, risk of collision, further regulations need to be developed, permission required.
- Satellite: comfortable application to understand critical data to monitor and understand crop development, drought, snow cover, and soil., limited spectral resolution, unavailability, low transfer speed, slow data delivery to end-users.
- Aircraft: can be economic above 500 hectares of contiguous cropland, plant conditioning – protection – fertilisation is implementable at economic level, high investment and maintenance cost, significant service cost, permission and regulations, complicated set up.

4. WATERAGRI solutions for training

4.1 Solutions for water retention and nutrient recovery in WATERAGRI.

The solutions for water retention and nutrient recovery in WATERAGRI are grouped into three groups as follows (Technology readiness levels (TRL) are a method for estimating the maturity of technologies during the acquisition phase of a program):

Framework Modelling (Group A):

- A1: Framework (TRL=3→6; UNINE),
- A2: Integrated physically-based terrestrial system models combined with data assimilation (TRL=3–4→6–7; FZJ),
- A3: Decision support system optimising irrigation scheduling and fertilisation (TRL=3→6; AGRICOLUS),
- A4: Water-vapour sorption isotherm and water retention characteristics model (TRL=2→5; USAL),
- A5: WebGIS for zoning landscape matrix (TRL=3→6; AGRICOLUS) and
- A6: Serious game (TRL=2→5; TUDELFT).

Water Retention Solutions (Group B):

- B1: Farm-constructed wetlands for water retention (TRL=3→7; ULUND),
- B2: Remote sensing pipeline (TRL=4→7; VULTUS),
- B3: Irrigation management and agrometeorological monitoring solutions (TRL=3→5; AGRICOLUS),
- B4:); Precision irrigation system (TRL=3→5; AGRICOLUS),
- B5: Enhanced water retainer product and concept (TRL=5→8; BZN),
- B6: Biochar for water retention (TRL=3→6; ALCN),
- B7: Tracer methods (TRL=3→6; BOKU),
- B8: Dewaterability estimation test apparatus (TRL=3→6; USAL).

Nutrient Recovery Solutions (Group C):

- C1: Farm-constructed wetlands for nutrient recovery (TRL=3→7; ULUND),
- C2: Drainage systems (TRL=3→5; ALCN),
- C3: Bio-based nutrient-collecting membranes (TRL=3→7; VTT),
- C4: Biochar adsorbents for nutrient uptake (TRL=3→6; ALCN),
- C5: Microfluidics (TRL=3→6; EDEN).

4.2 Farmers aspects: how to increase adaptability and acceptability of WATERAGRI solutions?

WATERAGRI partners identified affordable and easy-to-implement long-term technical and operational farm solutions, which are now in the development and testing phase. These solutions are intended for the farm-scale management of irrigation and fertilization practices using different water and nutrient sources. To make

WATERAGRI solutions more easily adaptable and useable for farmers and farm managers, the following table collects and categorizes the solutions based on their aims and the scale (on-site or laboratory) (Table 1).

Table 1: List of WATERAGRI solutions in a new structure making them more useable in practice.

1 Water and nutrient management for smart and sustainable agriculture	2 On-site water retention solutions	3 On site nutrient recovery solutions	4 Laboratory-scale tests:	5. Nutrient recovery solutions
1/1 Decision support system optimising irrigation scheduling and fertilisation 1/2 Remote sensing pipeline 1/3 Irrigation management and agro-meteorological monitoring solutions 1/4 Precision irrigation system 1/5 Serious gaming	2/1Farm constructed wetland 2/2 Enhanced water retainer product and concept 2/3 Biochar for water retention	3/1Farm constructed wetland for nutrient recovery 3/2 Drainage system 3/3 Bio-based nutrient-collecting membranes 3/4 Biochar adsorbents for nutrient uptake	4/1 Tracer Methods 4/2 Dewaterability Estimation	5/1 Nanocellulose membranes for nutrient recovery 5/2Microfluidic system for nutrient recovery

The structural changes in WATERAGRI solutions help the farmers to better understand the practical aspects and benefits of the solutions.

As defined in the previous table, the structured WATERAGRI solutions related to agricultural practices can be used by possible actors in agro-industry and agriculture. However, not all technologies are relevant for all actors. Therefore, we have summarised the solutions that could be used by the following specific agro-industrial and agricultural actors and could be more informative at a stakeholder workshop (see Table 2).

Table 2: WATERAGRI solutions in relation to the most relevant farm types.

Solutions involved in the training material	Crop farming	Crop farming + animal husbandry	Horticulture	Mushroom cultivation	Pond aquaculture	Agricultural biogas plant	Food, crop processing industry	Growing substrate manufacture
1/1Decision support system optimising irrigation scheduling and fertilisation	x	x	x	x				
1/2Remote sensing pipeline	x	x	x					
1/3Irrigation management and agro-meteorological monitoring solutions	x	x	x					
1/4 Precision irrigation system	x	x	x					
1/5 Serious gaming	x	x	x	x	x	x	x	x
2/1 Farm constructed wetland for water retention	x	x	x	x	x	x	x	x
2/2 Enhanced water retainer product and concept	x	x	x					x
2/3 Biochar for water retention	x	x	x	x				x
3/1Farm-constructed wetland for nutrient recovery	x	x	x	x	x	x	x	x
3/2 Drainage system	x	x	x		x	x		
3/3 Bio-based nutrient-collecting membranes	x	x	x	x	x	x	x	x
3/4Biochar adsorbents for nutrient uptake	x	x	x	x	x	x	x	x
4/1 Tracer method	x	x	x	x				x
4/2 Dewaterability estimation test apparatus					x	x		
5/1 Nanocellulose membranes for nutrient recovery	x	x	x	x	x	x	x	x
5.2 5/2Microfluidic system for nutrient recovery	x	x	x	x	x	x	x	x

5. Training in practice

5.1 Training objectives

The overall objective of the stakeholder training is to provide practical knowledge to make farmers understand and apply the practical application of WATERAGRI solutions, including the following: the forms, rise, quantitative characteristics, measurement, spatial and periodical dispersions, and density- and dispersion functions of drought. Applying the mechanisms, forms, measurement and calculation of the evapotranspiration. The ability to evaluate technological practices and activities of drought monitoring concerning agriculture and environmental management. The training provides advanced knowledge on drought monitoring and mitigation techniques, theory and practice of designing, theory of setting and installation, and handing over of plant water supply for irrigation systems. As a result of completing the course, attendees will be able to apply principles of advanced drought management as potential managers or professional experts.

The following topics are included:

1. Water and nutrient management for smart and sustainable agriculture (Chapter 5.2.1),
2. On-site water retention and nutrient recovery solutions (Chapter 5.2.2),
3. On site water retention solutions (Chapter 5.2.3),
4. Laboratory-scale water transport and dewaterability tests and methods (Chapter 5.2.4),
5. Nutrient recovery solutions (Chapter 5.2.5),

Keywords: water and nutrient management, water retention, nutrient recovery, drought damages, drainage, precision irrigation, remote sensing, nutrient loss, dewaterability,

5.2 WATERAGRI solutions

5.2.1. Water and nutrient management for smart and sustainable agriculture

1/1 A decision support system to improve irrigation and fertilization.

Specific field: water and nutrient management that integrates remote sensing, geographical data and global positioning system.

Goals:

- Optimised water and nutrient management for sustainable agriculture.
- Precision irrigation was further developed, allowing effective water resources for economic yield achievement.

Function, what is it good for:

- The decision support and management system improves soil fertility, and its functions are water infiltration, water holding capacity, structure, humus content, and nutrient supply.
- It contributes optimised use of available water resources.
- The precision irrigation system provides optimum water balance from topsoil to deeper layers depending on crop cultivates.

For adaptation and application: collecting data and information about land used:

- Information on the farm system's current irrigation and plant cultivation infrastructure.

- Mapping excess water risk
- Water resources for irrigation surface, groundwater.
- Soil moisture content, soil type, structure, physical-chemical characteristics,
- Crop type, water status, phenological stage, water demand for economic yield.

In practice, to apply:

- Consultation between the solution provider and farmers or farm managers to prepare the application of this solution.
- Site selection to determine fields will be irrigated and engaged in development.
- The cost of this solution is based on subscription.

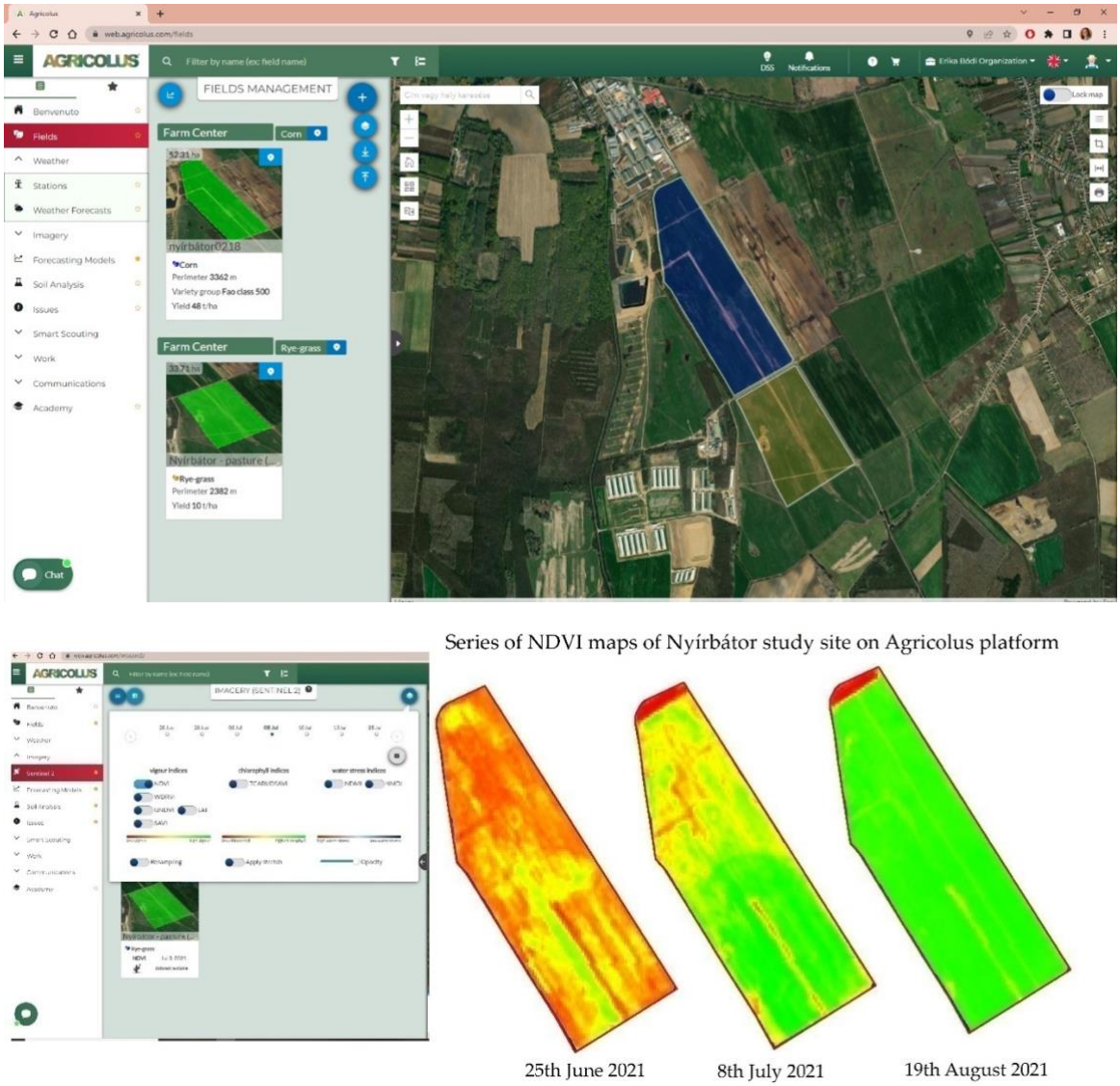

Figure 4. Hungarian case study site in Agricolus platform: Nyírbátor maize field and grassland pasture where precision irrigation practice was performed in years 2020, 2021 and 2022.

Remotely sensed data for water and nutrient management

The goal:

Remotely sensed data and satellite imagery data are widely available to monitor and manage agricultural land, crop cover, plant health, irrigation and nutrition efficiency.

Observation and monitoring for sustainable agriculture:

Satellites and observation systems since 2014: including Sentinel 1, Sentinel 2, and Sentinel 3, are available to observe land surface changes and vegetation phenology.

Functions of remote sensing products:

- Normalized Difference Vegetation Index (NDVI): vegetation biophysical parameters measured.
- Normalized Difference Water Index (NDWI).
- Surface Soil Moisture (SSM).
- Leaf Area Index (LAI).

This solution improves efficiency with precision fertilisation and irrigation at the economic yield level to reduce water demand and input cost for different cultivars and soil types.

Technical information:

- To access the Vultus Application Programming Interface, users must install the Postman platform.
- Select services are available as plant health, nitrogen prescriptions, and soil organic carbon.

In practice:

- This solution is suitable to lower input costs and to optimise irrigation in time and amount of water used.
- Remote sensing helps to define optimal water and nutrient application to achieve the economically best yield level.

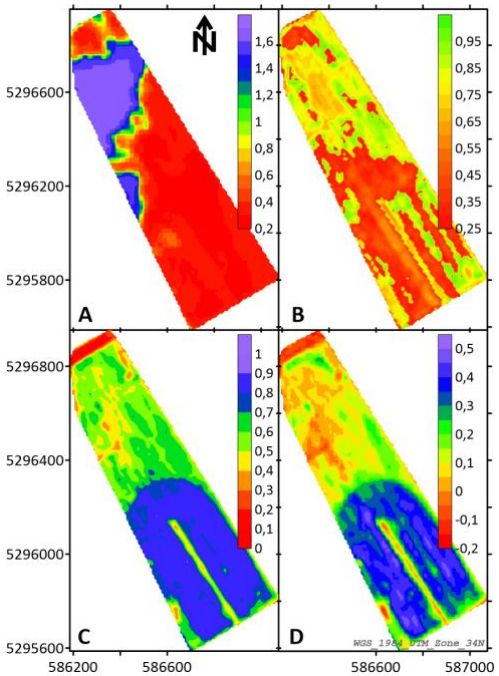

Figure 5: Remotely sensed data management included in factsheet by VULTUS.

AGRILEMMA - a Serious Game

The goal of AGRILEMMA:

AGRILEMMA is a board game to improve understanding of water retention and nutrient recovery solutions for all stakeholders: farmers, farm managers, farmer associations, agricultural chambers, policymakers,

AGRILEMMA in practice:

- Attractive game to model real situations in practice,
- Interactive learning medium with 4-6 players,
- How to manage situations, how to adapt to climate change,
- Effectively communicates with stakeholders who have not got technical knowledge,
- Good opportunity to get closer to younger and older generations,
- The estimated cost can reach 60 euros, which includes the game and additional elements.

AGRILEMMA is an interactive board game for sustainable agriculture:

- To reach and maintain economic yield,
- To manage excess and shortage of water,
- Water retention and nutrient recovery capacity information play a major role in developing farming technology.

Figure 6: Playing with AGRILEMMA at the General Assembly meeting held in Vienna, 2022

More information and references from wateragri.eu

5.2.2. On-site water retention and nutrient recovery solutions

Farm-constructed wetlands for water and nutrient retention

The goal:

Farm Constructed Wetlands can store the surplus of water for irrigation and nutrient retention with additional benefits such as improving water balance in the soil of surrounding areas.

Provide complex ecosystem services:

- Temporary storage during heavy rainfall events,
- Retention for soluble and particulate nutrients,
- Wetland conservation,
- Improving the microclimate and thermal comfort,
- Providing an opportunity for fish production in pond aquaculture.
- Treatment and purification of effluent and wastewater from agricultural production: animal husbandry, food processing activity, biomass-based renewable energy generation.

In practice:

- The technical construction depends on soil structure and land site sensitivity; in some cases, the impermeable cover is recommended to retain water in the system.
- Water rights implementation permit can be required to construct a wetland system, for example, on an arable land site. (Environmental Court).
- In the European Union, some kind of subsidies is available for construction.
- The maintenance period can be calculated for decades.
- Temporary removal of the bottom sludge layer is needed to maintain useful water body levels in the system.

Figure 7: Farm constructed wetland in Italy, 2021

The short video “Wetlands in the WATERAGRI Project – Lund University” introduces wetlands with a focus on nutrient reduction.

https://www.youtube.com/watch?v=TpemgfRuCaE

For more information, see, for example, the European NWRM Platform.wateragri.eu

Biochar for water retention and nutrient uptake

Specific solutions using biochar as a filter material:

- Biochar is generated from biomass combustion at high temperatures without oxygen.
- Biochar is registered as a component according to the new EU fertiliser regulation (1009/2009).

Current application of biochar:

- soil amendment and conditioner,
- additive for growing media production,
- compost activator to mitigate greenhouse gas and odour emissions, nitrogen loss,
- useful microbe carrier for plant growth-promoting microbe strains in composting and soil inoculation,
- organic, organo-mineral fertiliser and compost production to improve long-lasting effects on soils,
- in bioremediation technologies to immobilize toxic inorganic and organic pollutants in soil matrix or effluent streams.

Multi-layer filter material for water and nutrient retention using biochar:

- Farm-constructed wetland filter material to treat wastewater in two different structures with and without plant cover,
- Filter system for subsurface drainage water treatment: filter can be inserted into the drainage pipe,
- Bio-inspired multi-layer filter system to retain dissolved macro-nutrients, an on-site solution including plant cover.

In practice, how to apply:

- Depending on the vertical structure, a multi-layer filter medium for wetlands requires gravel, activated biochar, zeolite, an organic layer, and selected plant species for wetland construction.
- Filter system for subsurface drainage water treatment requires drainage pipe, and the outlet is accessible for insertion filters,
- The bio-inspired multi-layer filter system in arable land management requires filter materials in a vertical structure with a planted surface zone, drainage and collector pipes, and monitoring sensors installed on site.

Monitoring:

- Periodic monitoring, the filter medium needs to be changed in case of heavy rainfall events, saturated by soil particles and other constituents,
- Sensor-based real-time monitoring for pH, EC, nitrate, ammonium nitrogen, orthophosphate,
- temperature, soil moisture and temperature

Figure 8: Biochar for water retention and nutrient recovery by alchemia-nova, 2022

For more information: wateragri.eu

5.2.3. On site water retention solutions

Enhanced Water Retainer Concept

The goal:

- Water Retainer is an organic-based soil conditioner to retain and adsorbs water in the rooting zone to support plant development in the most delicate phases.
- There are no residual substances after the application 3-4 months later because all constituents are biologically decomposable.

Function in crop farming:

- Due to the hydrophobic nature of the Water Retainer, water is retained after spraying on the soil surface,
- adsorbed and retained water in the rooting zone will be readily available for plants,

Farming benefits:

- better germination, better root development and better hydration,
- substantially lower drought damages, longer resistance to drought,
- higher yield,
- less soil compaction,
- reduced irrigation water consumption meaning significant water saving (up to 30 –50% of the irrigation water used),
- Utilizing the product in fields without irrigation can result in extended endurance of crops during drought periods and better yield.

Soil with ideal water content supported by Water Retainer product means long-term benefits in farming.

In practice:

- Different spraying machines are appropriate for applying Water Retainer in land farming.
- In plant development stages, after germination,2-2.5 mm irrigation is needed to avoid localised dehydration of the plant tissues.
- The average and recommended doses range between 5-10 litres for 1 hectare.

Figure 9: Water Retainer under testing in Hungary, 2022

For more information : wateragri.eu

5.2.4. Laboratory-scale water transport and dewaterability tests and methods

Dewaterability Estimation Test Apparatus (DET)

The goal:

This solution is indispensable for determining readily removable liquids from wastes and by-products originating from agricultural production, food processing, renewable energy generation, and wastewater treatment.

Importance of WATERAGRI:

- Dewatering digestate, animal slurry, wastewater sludge, bed sludge from the farm-constructed wetland,
- Treating and dewatering: biochar-based filter medium, runoff sediment.

In practice:

Key components of the device (in no particular order) are the slot funnel, camera, light-emitting diode, light diffuser, sensors to measure temperature and humidity, laptop (hosting the DET software), fan and thermal paste (heat sink compound) for cooling.

For more information: Cristian Clausner E-mail: C.Clausner@salford.ac.uk

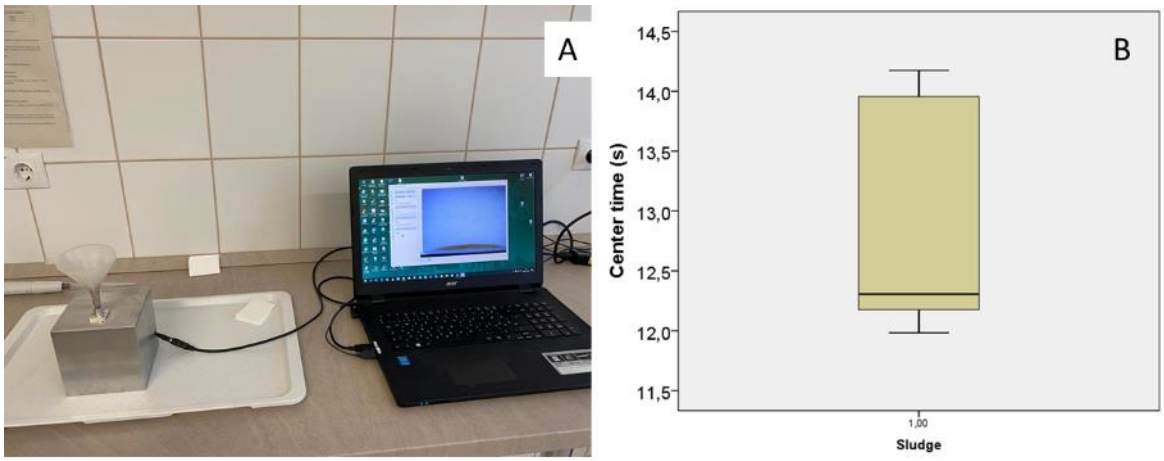

Figure 10: DET technology tested by UNIDEB in 2021

Tracer Methods

Tracer methods can provide valuable information on water transport dynamics in soils. Based on profiles of hydrogen and oxygen isotopes, this method gives feedback about water flux, infiltration, and retention in soil vertical profile.

The procedure is based on the following steps:

Soil sampling down to 60 - 150 cm or even deeper if possible,

1. analysis of the isotopic composition,
2. analysis of gravimetric water content,
3. comparison of the temporal variation of the isotopic composition,
4. peak-shift method to quantify water flux.

The practical importance of Tracer Methods:

- risk assessment for polder generation from heavy rainfall events,
- measurements for land sites to control soil compaction, erosion and degradation,
- monitoring the frequent application of low dry matter animal slurries, digestates,
- monitoring soil cover on communal waste landfill sites,
- monitoring soil profile in orchards and vineyards,
- monitoring fluvo-aquic soil profile,
- Control on water flux in plant growing substrates.

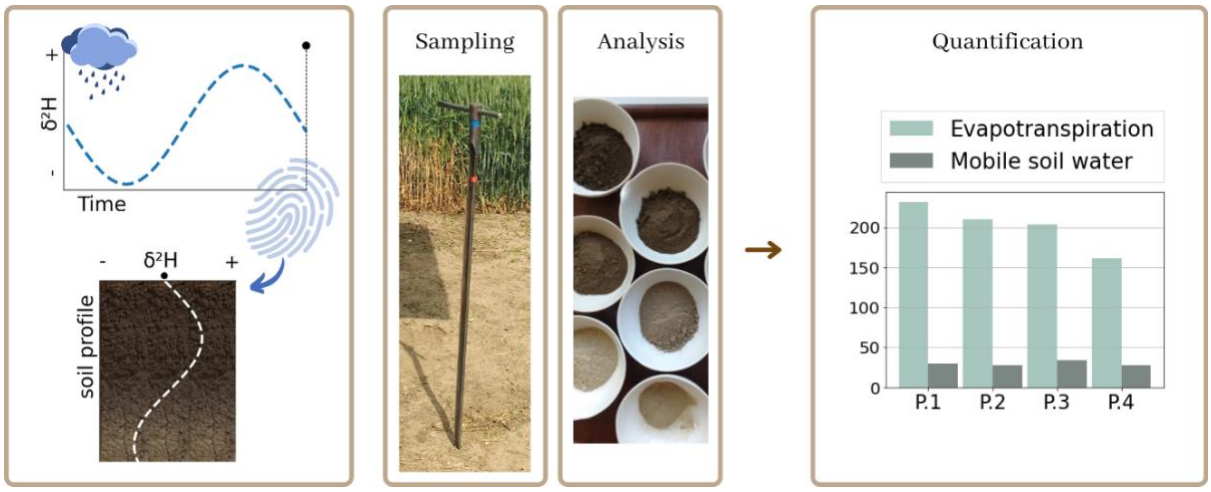

Figure 11: Tracer method by BOKU included in factsheet

For more information: wateragri.eu

5.2.5. Nutrient recovery solutions

Nanocellulose membranes for nutrient recovery

Nanocellulose membranes in runoff treatment are considered one of the most updated materials for nutrient recovery solutions that are biologically degradable.

In case of overloading, their biological structure enables them to completely recycle for soil amending or fertiliser without environmental risk.

Potential use:

- phosphorus and nitrogen removal,
- natural freshwater quality conservation,
- agricultural land runoff treatment,
- horticultural production,
- pond aquaculture water body treatment in case of water discharge at the end of the fish harvesting period,
- effluent treatment from intensive fish production in a closed system,
- leakage water treatment on waste landfill sites,

In practice:

- The membrane production is environmentally friendly; there is no risk of pollutant generation.
- This solution is under development; further scale-up tests need to be implemented.

Figure 12: Nanocellulose membrane technology by VTT included in factsheet

The nanocellulose membrane material has been produced in sheets of length 10 m, width 30 cm, thickness ~25 µm) manufacturing uniform and functionalized for enhanced affinity using roll-to-roll (R2R).

Reference and demonstration: wateragri.eu

Microfluidic system for nutrient recovery

The Microfluidic system is designed to effectively treat agricultural wastewater and can be connected to the drainpipe.

Potential use:

1. wastewater generated from animal husbandry,
2. pond aquaculture wastewater treatment,
3. wastewater originating from closed fish production,
4. food processing, industrial wastewater treatment,
5. wastewater and effluent generated from renewable energy production,
6. drainage, leakage water treatment from mushroom substrate production, biomass composting units,
7. landfill leakage water treatment.

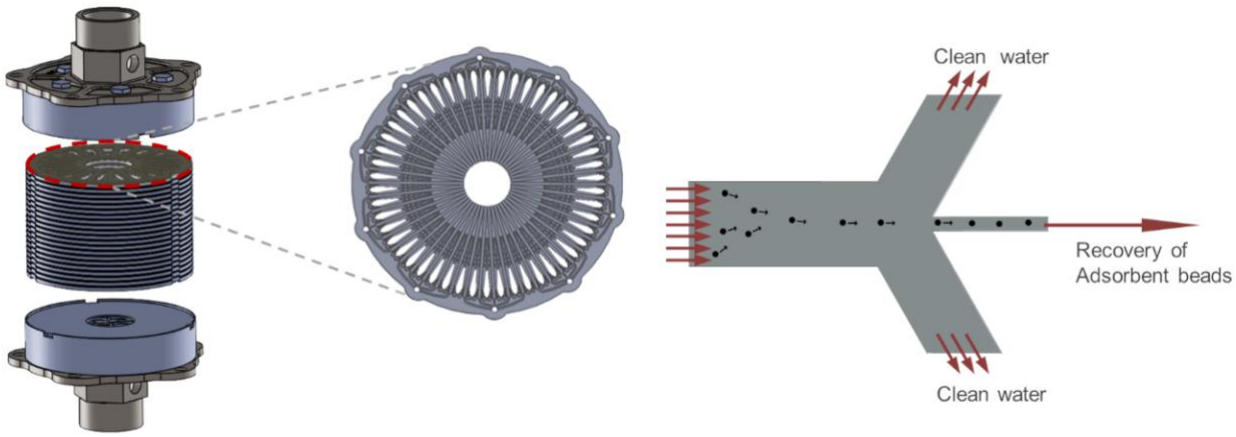

Figure 13: Microfluidics for nutrient recovery included in factsheet by EDEN, 2022

In practice:

- a continuous process with *in-situ* recovery and regeneration of adsorbents,
- the system is composed of filtrating discs,
- the capacity of processing up to 100L/sec of water.
- Each microfluidic CD core has a diameter of 10 cm and a thickness of 1 mm.
- The device efficiently guides the microbeads for collection at a significantly higher concentration, up to 1,000,000-fold.
- The microfluidic system requires an external pump to circulate agricultural wastewater and includes a prefiltration cartridge, a microfluidic stacked CD cartridge, and a regeneration agent reservoir.

Project website: wateragri.eu

5.3 Training materials

Training material 1: **Deliverable 1.2 report.** This report represents a handbook with a short introduction of the WATERAGRI project, a complete matrix for solutions to link them to related farm types and detailed information about solutions to become transparent WATERAGRI solutions mostly for farmer audience.

Training material 2**:** includes 5 slideshows according to the agenda in 5.4 Training delivery. Slideshow will be available to download for the participants of the training. The WATERAGRI Solution Slideshows provide more practical information for each listed farm type with updated water retention and nutrient recovery responses. The first slideshow is s short introduction to the WATERAGRI project, and the second one is about drought damage, and excess water in agriculture, highlighting the recent drought conditions. The WATERAGRI Solutions Slideshow can reflect challenges in different farm systems that operate in current European agriculture and link WATERAGRI solutions to relevant problems to be solved. The slideshows focus on current and real situations that are manageable and to be solved on farms, composting, and wastewater treatment plants to become more sustainable in operation, to retain more water to be recycled in the technology or for irrigation, to recover more nutrient, to replace inorganic fertilisers for plant nutrition. Each solution listed in Chapter 5.2. is represented in three slides, emphasizing their relevance in practice from a farmer's aspect. Current problems and challenges are collected (with photos and data from the operation) in parallel with how the solution can provide the updated solution for water retention or nutrient recovery. To raise awareness, Agricultural subsidies for water and nutrient retention measures will also be introduced for farmers and farm advisors during the training, as potentially how the water and nutrient retention measures could be financed at the farm scale.

5.4 Training delivery

The complete training requires 4 hours and includes the below-listed items in the agenda in case of face-to-face or virtual meetings that will be supplemented with an onsite demonstration of selected WATERAGRI solutions. The aim of the training is to provide updated knowledge not only for farmers but also for representatives of current agriculture on water retention and nutrient recovery to improve water management and sustainability of crop farming and production regarding the new programming period of the Common Agricultural Policy, 2023-2027.

8.30-9.00 Registration

9.00-9.10WATERAGRI project from the perspective of farmers

9.10-9.30 Drought damages, excess of water in agriculture

9.30-10.30WATERAGRI solutions Part 1

10.30-10.45 Coffee break

10.45-11.45 WATERAGRI solutions Part 2

11.45-12.30 Questions & answers and discussion

12.30-13.00 Agricultural subsidies for water and nutrient retention measures

6. Additional Reading Material for Training

The table below references relevant WATERAGRI project reports and other material containing additional information about each solution that is part of the training material. Deliverables are available on the project website wateragri.eu.

Table 3: Additional information for WATERAGRI solutions

Solutions involved in the training material	Related group	Presentations on YouTube channel*	Related deliverables are available	Fact sheets
Decision support system optimising irrigation scheduling and fertilisation (A3)	5.2.1 Water and nutrient management for smart and sustainable agriculture		D2.3: Remotely sensed data D3.1: Assessment of Use of Remotely Sensed Vegetation to Improve Irrigation	
Serious gaming (A6)	5.2.1 Water and nutrient management for smart and sustainable agriculture		D1.3 Serious game	x
Remote sensing pipeline (B2)	5.2.1 Water and nutrient management for smart and sustainable agriculture	x	D2.3: Remotely sensed data D3.1: Assessment of Use of Remotely Sensed Vegetation to Improve Irrigation D5.2: WATERAGRI Solution Test Findings	x
Irrigation management and agrometeorological monitoring solutions (B3)	5.2.1 Water and nutrient management for smart and sustainable agriculture	x	D3.1: Assessment of Use of Remotely Sensed Vegetation to Improve	x

			Irrigation D5.2: WATERAGRI Solution Test Findings	
Precision irrigation system (B4)		x	D3.1: Assessment of Use of Remotely Sensed Vegetation to Improve Irrigation D5.2: WATERAGRI Solution Test Findings	x
Farm-constructed wetland (B1)	5.2.2 On-site water retention and nutrient recovery solutions	x	D3.2: Assessment of Water Retention Methods D5.2: WATERAGRI Solution Test Findings	
Enhanced water retainer product and concept (B5)	5.2.3 On site water retention solutions	x	D3.2: Assessment of Water Retention Methods D5.2: WATERAGRI Solution Test Findings	x
Biochar for water retention (B6)	5.2.2 On-site water retention and nutrient recovery solutions	x	D4.7: Progress report on the development of the Nutrient Recovery Solutions D5.2: WATERAGRI Solution Test Findings	
Tracer method (B7)	5.2.4 Laboratory-scale water transport and dewaterability tests and methods		D3.2: Assessment of Water Retention Methods D5.2: WATERAGRI Solution Test Findings	x
Dewaterability estimation test apparatus (B8)		x	D3.2: Assessment of Water Retention Methods D5.2: WATERAGRI Solution Test Findings	x
Farm-constructed wetland for nutrient recovery (C1)	5.2.2 On-site water retention and nutrient recovery solutions	x	D4.7: Progress report on the development of the Nutrient Recovery Solutions D5.2: WATERAGRI Solution Test Findings	
Drainage system (C2)	5.2.2 On-site water retention and		D4.7: Progress report on the development of the	x

	nutrient recovery solutions		Nutrient Recovery Solutions D5.2: WATERAGRI Solution Test Findings	
Bio-based nutrient-collecting membranes (C3)	5.2.5 Nutrient recovery solutions	x	D4.7: Progress report on the development of the Nutrient Recovery Solutions D4.4 Description of Developed Membrane-based Solution for Nutrient Recovery D5.2: WATERAGRI Solution Test Findings	x
Biochar adsorbents for nutrient uptake (C4)	5.2.2 On-site water retention and nutrient recovery solutions	x	D4.7: Progress report on the development of the Nutrient Recovery Solutions D5.2: WATERAGRI Solution Test Findings	x
Microfluidics(C5)	5.2.5 Nutrient recovery solutions	x	D4.7: Progress report on the development of the Nutrient Recovery Solutions D5.2: WATERAGRI Solution Test Findings	x

*youtube channel (https://www.youtube.com/@WATERAGRIproject385)

7. Summary

The stakeholder training material has been developed according to the Grant Agreement, including teaching material for all WATERAGRI solutions. Stakeholders will be invited to attend early engagement workshops.

The Agreement includes all solutions in three different groups: Framework Modelling (Group A), Innovative and Sustainable Water Retention Solutions (Group B), and Nutrient Recovery Solutions (Group C), changed due to opinions and feedback collected from farmers and farm managers were participated in WATERAGRI workshops. AGROGEO emphasized that all updated water retention and nutrient recovery solutions get closer to all relevant stakeholders identified during the early engagement. This procedure resulted in a new structure that is clearly transparent and more practical, listed as 1 Water and nutrient management for smart and sustainable agriculture; 2 On-site water retention and nutrient recovery solutions; 3 On site water retention solutions; 4 Laboratory-scale water transport and dewaterability tests and methods; 5 Nutrient recovery solutions.

Authors and contributors of this Deliverable created the training material that is comprised of two main parts:

1. This report can be used as a handbook providing general information about all WATERAGRI solutions and their background in relation to application and operation in a relevant environment and current climate challenges.
2. PowerPoint slides providing updated information about the WATERAGRI project and how to use solutions in practice. The slides are organised in the following five presentation slideshows: (1) WATERAGRI project from the perspective of farmers, (2) Drought damages, excess of water in agriculture, (3) WATERAGRI solutions Part 1, (4) WATERAGRI solutions Part 2, and (5) agricultural subsidies to apply WATERAGRI solutions.

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