Transfarm4.0

Big and Smart Data Management Pilot action case study 3: Sensor data acquisition for precision Viticulture in a Fiware data lake

D.T2.2.9.; D.T2.2.10; D.T2.2.11; D.T.2.2.12; D.T2.2.31

Version 1

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D.T2.2.9: One joint industrial undertaking in big and smart data management (co-design of case study 3)

Grapevine quality is influenced by several factors, including the grapevine and rootstock cultivar, cultivation practices, and the training and trellising system adopted. Additionally, environmental elements enormously impact plant physiology, yield, and quality. Among others, topography, in particular, elevation and exposure, have a direct and indirect effect on the phenological stages of the vineyard. Climatic conditions such as radiation, precipitation, temperature, and humidity are most frequently monitored at three levels:

- Macroclimate refers to the climatic conditions of a larger geographic area, such as a wine region. At this level, the climate and the actual weather govern radiation, temperature, humidity, and wind.
- Mesoclimate usually refers to a smaller geographic area within a wine region, such as a single vineyard. In this case, climatic conditions are highly influenced by the macroclimate and topography.
- Each vineyard has different microclimatic areas (Figure 1). These areas are influenced by the macro-and mesoclimate, topography, trellising system in place, vine spacing (row and plant distance), canopy management (pruning, shoot thinning, shoot topping, and leaf removal), nutrient supply, irrigation, soil type and depth. Radiation, humidity, temperature, and airflow within the vineyard's microclimate directly affect the plants' phenological stages, yield, and quality of the grapes.

Microclimate monitoring would help prevent the spread of pests and pathogens and make the optimal cultivation decisions for each *terroir*. Defined by its climate, topography, grapevine cultivar, cultivation technique, and oenological practices, *terroir* is one of the most important concepts in quality winemaking. Wine appellations are very much defined by their unique climatic conditions, and in this regard, monitoring the single vineyards is greatly relevant.

Climate change is significantly affecting many sectors of agriculture. Even in regions where the annual precipitation is not changing, yearly pattern shifts are noticeable. Viticulture is highly sensitive to ecological parameters and particularly to rainfall distribution, which influences the grapevine and the wine's phenological stages, vegetative growth, yield and quality. In Hungary, the average annual rainfall is between 500 and 700 mm, with significant differences among the wine regions.

Grapevine irrigation is still confined to table-grape production, but the changing climate has led wine grape growers to establish and run irrigation systems.

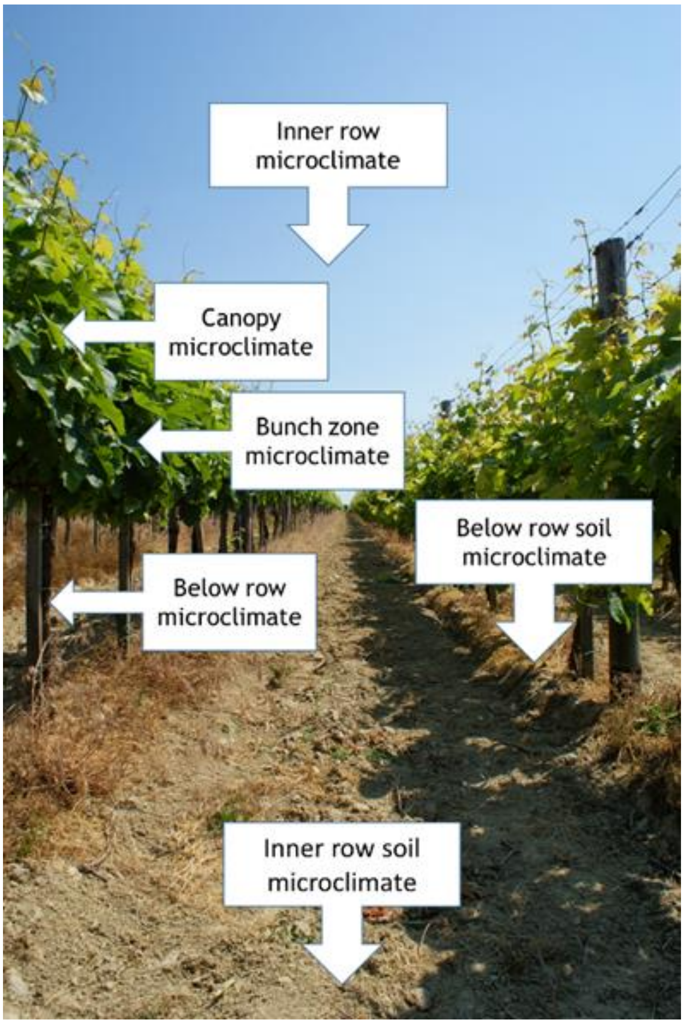

Figure 1.: Vineyard canopy microclimate model

There are several scientific reports on grapevine irrigation. However, their data are only partially applicable to Hungary due to its unique ecological conditions (e.g. soil types), growing practices (e.g. trellising system, canopy management) and unique cultivars.

This pilot action aims to implement a smart data acquisition system in agriculture, allowing farmers to monitor and analyse relevant parameters and act accordingly. Thus, this pilot action belongs to the innovation domain of "big and smart data management".

FIWARE, an open-source platform supported by the European Commission as part of the Digital Agenda 2020 (https://ec.europa.eu/digital-single-market/en/news/fiware-european-success-story), was created to enable smart data acquisition.

The FIWARE Context Broker is the core component, which gathers, manages and provides access to information from different sources (for example, sensor nodes). FIWARE also aims to be used in agriculture. Creating a FIWARE data acquisition system, would allow monitoring of several parameters relevant to farmers. The sensor data are acquired at several wireless sensor nodes and sent to the FIWARE Context Broker, where they are stored and can be analysed. Since FIWARE is an open-source platform, no license costs occur. By applying the FIWARE data acquisition system, different irrigation systems in this pilot action will be monitored and evaluated, considering canopy microclimate and plant physiological status. Based on the big data provided by the network, an efficient irrigation plan specific to the terroir, cultivar and cultivation practices would be established.

1 Members of the pilot action

- Hungarian University of Agriculture and Life Sciences (Hungary) – PP6
- Agrárinformatikai Klaszter (AgroIT Nonprofit Kft.) (Hungary) – PP7
- Linz Center of Mechatronics GmbH (Austria) – PP8

2 Tasks of the members

2.1 Task of the Hungarian University of Agriculture and Life Sciences (MATE) (PP6)

The Hungarian University of Agriculture and Life Sciences (MATE) is one of the leading education and research institutions in viticulture with experience in scientific investigations. Within the action, MATE is responsible for the viticultural background and relations with the farmer.

More in detail, MATE proposes to be responsible for:

- Defining a specific test scenario
    - Choice of the model farm and relations with the owner
    - Definition of the parameters (data) to be monitored
- Providing the model farm
    - Infrastructure
    - The organising and implementation of the model farm, which the partners would support
- Analysing data where LCM can assist with knowledge in machine learning, artificial intelligence, and mathematical models
    - Acquisition/organisation of reference data
    - Data validation via field proximal instrumental measurements (e.g. leaf gas exchange, leaf water potential)

2.2 Tasks of Agrárinformatikai Klaszter (AgroIT Nonprofit Kft.) (Hungary) (PP7)

The AgroIT Cluster's primary objective is to provide IT services appropriate to the farmers' needs, increasing their efficiency and innovative potential. The cluster is also responsible for developing the afterlife commercialisation of the technological solutions tested within the action.

To support this initiative, AgroIT has created a preliminary Lean Canvas model specifying (Fig. 2):

- The main issues prevalent in grape production to be addressed by using precision farming solutions.
- The proposed solutions/tools that can be implemented to manage the prevailing challenges.
- Transfarm 4.0 UVP and the unfair advantages that make the model commercially viable and sustainable.
- Target markets and early adopters.
- The cost structure and revenue stream possibilities of the model.

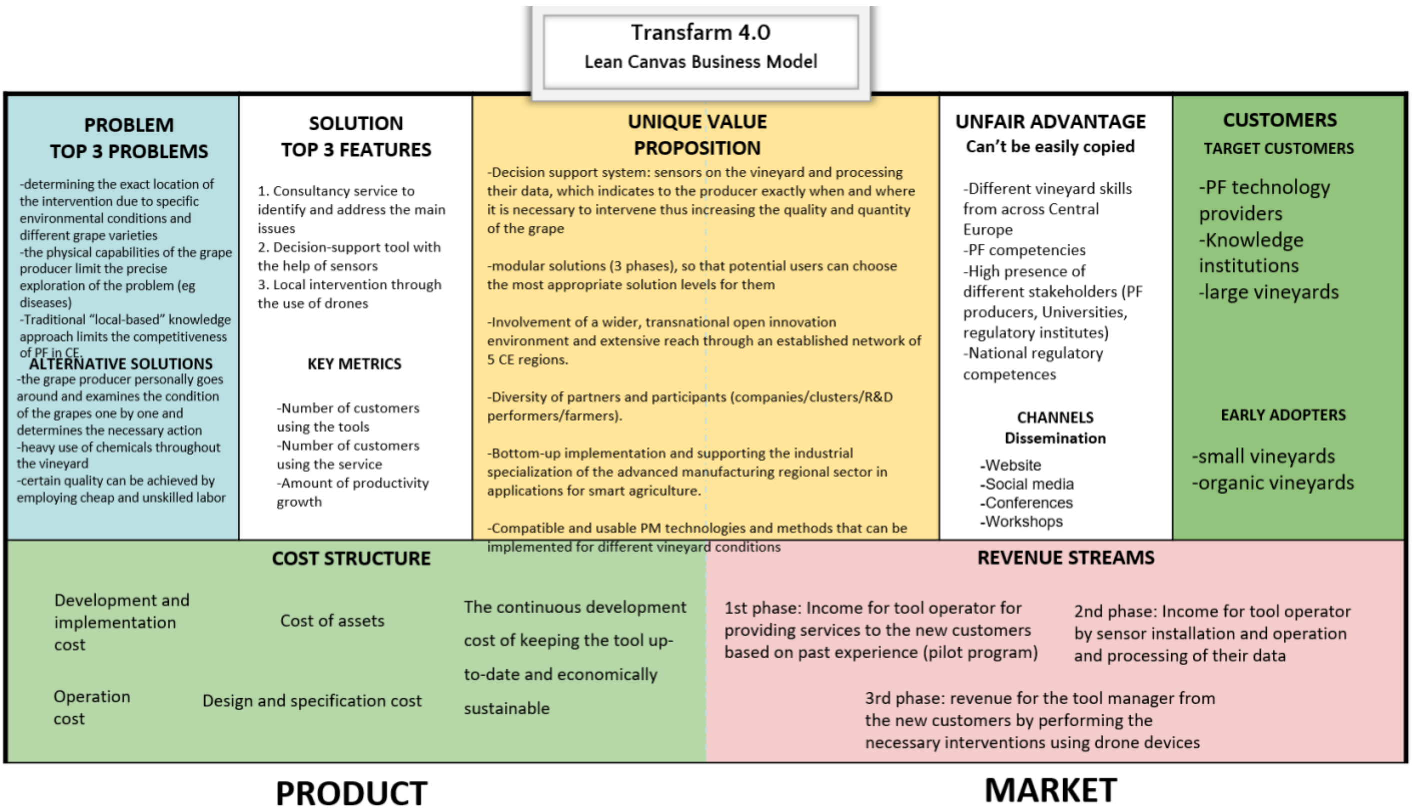

Figure 2: Lean Canvas model (Source: AgroIT Nonprofit Ltd.)

Furthermore, the proposed business model specifies the main participant groups/ stakeholders, the value propositions, and transactions between the actors to address the model's strengths, weaknesses, threats, and opportunities (Fig. 3).

The model is made up of the following components:

- **Tech RD&I-module**, to set up a knowledge triangle-based living lab to test innovative technologies, and whose aim is to support the establishment of a regional RD&I-framework to develop the region's competitiveness further.
- **Data Management-module,** to analyse and keep track of production and consumption patterns, thus assessing and monitoring the competitiveness of the developed solutions.
- **Training-module,** to prepare vineyards/grape producers to implement the new technologies and provide HR resources to support the professional work within the regional RD&I-framework.
- **Financial-module,** to provide financial support for the transference and replication of good practices. To ensure that the innovations developed within the regional RD&I-framework are transferred and replicated, prompting improved quality, quantity, and competitiveness.

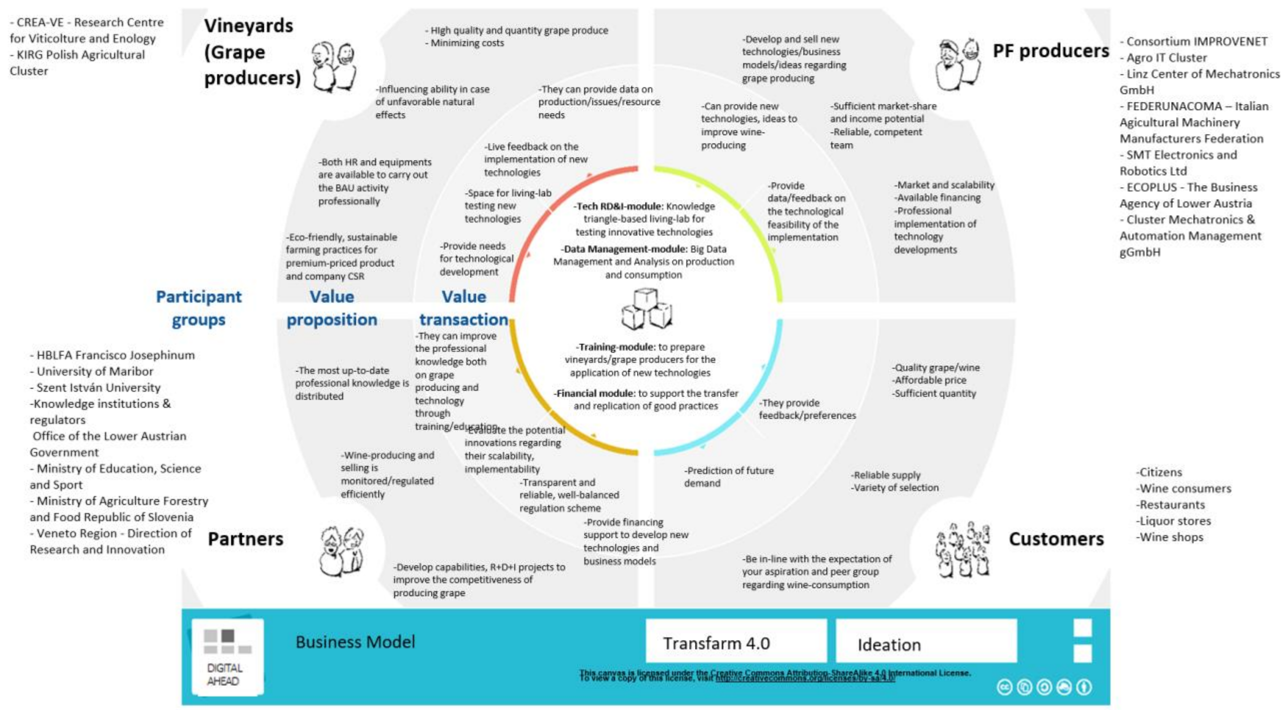

Figure 3: Proposed business model (Source: AgroIT Nonprofit Ltd.)

2.3 Tasks of Linz Center of Mechatronics GmbH (LCM) (PP8)

LCM is a specialist in mechatronics (electronics, sensors, communication theory, IoT), which proposes to create the FIWARE data acquisition system, including delivery and visualisation of the data.

More in detail, LCM proposes to be responsible for:

- Creation of the FIWARE data acquisition system
    - Wireless sensor nodes
    - FIWARE Context Broker
    - Data transfer from the sensors to the FIWARE Context Broker
    - Visualisation of the sensor data (at a web platform)
- Hardware:
    - Sensors
    - Wireless sensor nodes
    - Server system for the FIWARE Context Broker
- Software:
    - Implementing the data transfer from the sensor to the FIWARE system
    - Designing, implementing and optimising the software at the FIWARE platform
    - Possibility to integrate additional data (for example, meteorological data, weather forecast)

Thus, LCM is responsible for the whole data acquisition system consisting of sensor data acquisition, data transfer to the FIWARE Context Broker, data storage in a database, and visualisation (at a web platform).

Deliverable D.T2.2.10: Small-scale precision farming projects – (case study 3 – bigdata)

3 Model vineyard:

The vineyard is located in Tata (Hungary), belonging to the Neszmély wine region, in the north-east part of Transdanubia, in the Komárom-Esztergom County. The vineyards of this wine region are situated on the slopes and plateaus of Bakony, Vértes, Gerecse, Pilis, Visegrádi mountains and Komárom-Esztergomi plateau. The western border of the wine region is the Little Hungarian Plain, while the river Danube edges it in the north. The region's climate is continental, moderately dry and warm or partially moderately cool and dry. The average annual temperature is 10.0°C. The vineyards are slightly affected by late spring and early autumn frosts. The annual amount of sunlight is 1950-2000 hours. The yearly rainfall is 550-650 mm. The main bedrocks are loess and sandy loess; the soils are alkaline, calcareous and moderate to poor in humus. Cambisols, chernozem and leptoso l soil types are prevalent. In certain areas, the soils are fairly or moderately eroded.

- The effect of the irrigation is monitored on 3 plots (Figure 3):
  - Control (rainfed)
  - Subsurface Drip Irrigation (SSDI)
  - Surface Drip Irrigation (SDI)
- The effect of climatic conditions on the *terroir* is investigated by comparing two plots, one in Tata, Látóhegy (160 metres above the sea level), and the other in Dunaszentmiklós (250 metres above the sea level).

The grapevine cultivar involved is Hárslevelű. This cultivar is highly vigorous, with large loose bunches. The overall surface in Hungary is 1,497 hectares. The vines in the experimental plots are trained to a low-cordon system with vertical shoot positioning.

4 Monitored parameters and sensors:

Monitoring the soil and plant physiological status is required to obtain reliable information for big and smart data management, which can assist irrigation planning and *terroir* assessment (Table 1, Fig. 4). For this reason, automated sensor data were regularly validated via field proximal instrumental measurements (e.g. leaf gas exchange, leaf water potential). Therefore, in this proposal 3 different sensor distribution plans were introduced:

- Fully equipped: optimal numbers of sensors that collect reliable data for both big and smart data management and cover the entire experimental field, considering the within-vineyard variability caused by soil inhomogeneity and differences in the plant development (Table 2).
- Moderately equipped: this plan provides slight coverage of the experimental plot and collects data for reliable big and smart data management (Table 3).
- Low-equipped: minimal numbers of sensors which collect data for big and smart data management and irrigation control. This version does not cover the experimental plots, and only supplies point data (Table 4).

Table 1: Type of sensors

Treatments	Soil probes	Plant sensors	Mesoclimate sensors
Rainfed	Soil moisture, temperature and EC in-row sensors, in 2 depths	Infrared canopy temperature sensors Canopy NDVI sensors Canopy PRI sensors	Meteorology station at the vineyard (usual sensors + PAR sensor + global irradiance sensor)
Surface drip irrigation	Soil moisture, temperature and EC in-row sensors, in 2 depths		
Subsurface drip irrigation	Soil moisture, temperature and EC in-row sensors, in 2 depths		

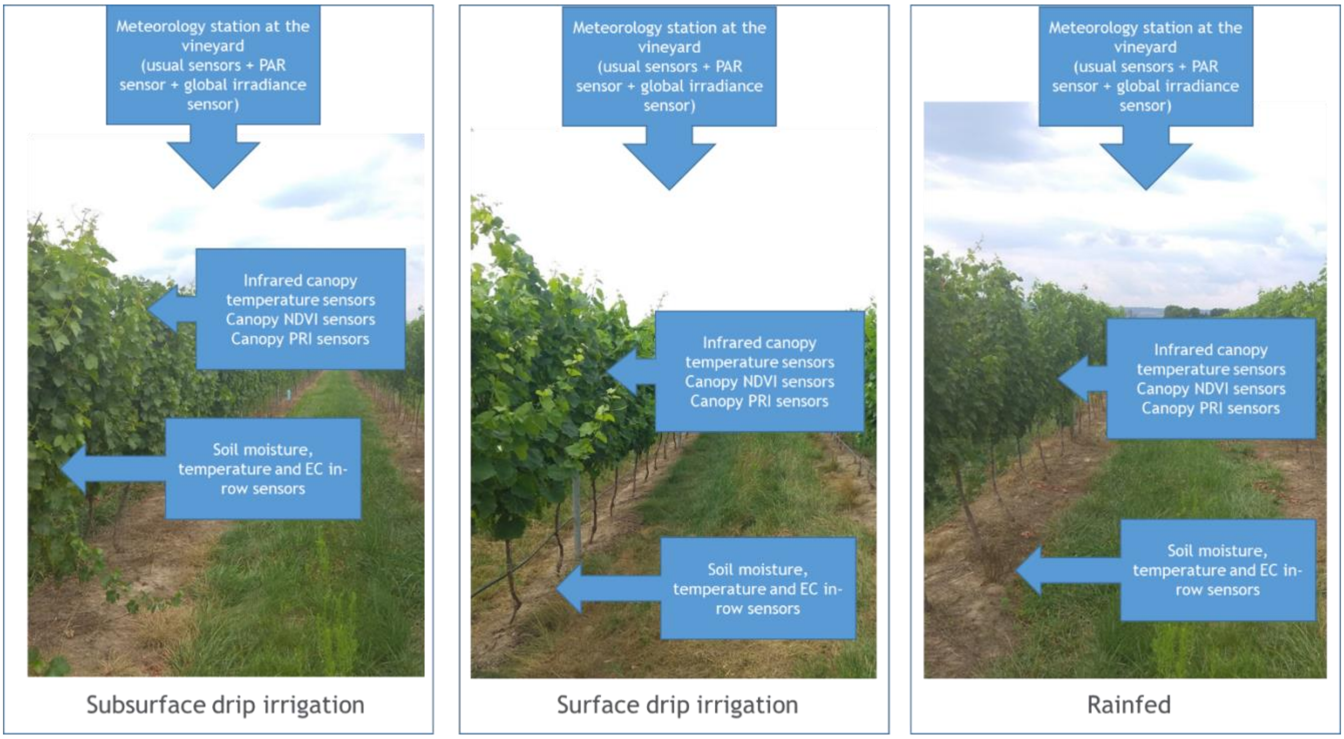

Figure 4: Sensor arrangement in the experimental field

Experimental design

Table 2: Full-equipped plot

Row # in treatment	3	2	3	2	3	2
Row Unit #	**SSDRIP**	**SSDRIP**	**SDRIP**	**SDRIP**	**Rainfed**	**Rainfed**
	Observed canopies	***Equipped row***	**Observed canopies**	***Equipped row***	**Observed canopies**	***Equipped row***
1						
2						
3						
4		**IRT, NDVI, PRI, SF, ZL6**		**IRT, NDVI, PRI, SF, ZL6**		**IRT, NDVI, PRI, SF, $NDVI_{ref}$, PRI_{ref}, ZL6**
5						
6						
7						
8		**IRT, NDVI, PRI, SF, T-12, ZL6**		**IRT, NDVI, PRI, SF, T-12, ZL6**		**IRT, NDVI, PRI, SF, IRT_{refDry}, IRT_{refWet}, ZL6**
9						
10						

11						
12		**IRT, NDVI, PRI, SF, ZL6**		**IRT, NDVI, PRI, SF, ZL6**		**IRT, NDVI, PRI, SF, T-12, ZL6**
13						
…						
17						

SSDRIP=Subsurface drip irrigation SDRIP= Surface drip irrigation

Table 3: Moderately equipped plot

Row # in treatment	3	2	3	2	3	2
Row Unit #	**SSDRIP**	**SSDRIP**	**SDRIP**	**SDRIP**	**Rainfed**	**Rainfed**
	Observed canopies	***Equipped row***	**Observed canopies**	***Equipped row***	**Observed canopies**	***Equipped row***
1						
2						
3						
4		**IRT, NDVI, PRI, SF, ZL6**		**IRT, NDVI, PRI, SF, $NDVI_{ref}$, PRI_{ref}, ZL6**		**IRT, NDVI, PRI, SF, IRT_{refDry}, IRT_{refWet}, ZL6**
5						
6						
7						
8		**IRT, NDVI, PRI, SF, T-12, ZL6**		**IRT, NDVI, PRI, SF, T-12, ZL6**		**IRT, NDVI, PRI, SF, T-12, ZL6**
9						
…						
17						

SSDRIP=Subsurface drip irrigation SDRIP= Surface drip irrigation

Table 4: Low-equipped plot

Row # in treatment	3	2	3	2	3	2
Row Unit #	**SSDRIP**	**SSDRIP**	**SDRIP**	**SDRIP**	**Rainfed**	**Rainfed**
	Observed canopies	***Equipped row***	**Observed canopies**	***Equipped row***	**Observed canopies**	***Equipped row***

1						
2						
3						
4		**IRT, NDVI, PRI, SF, T-12, NDVI$_{ref}$, ZL6**		**IRT, NDVI, PRI, SF, PRI$_{ref}$, T-12, ZL6**		**IRT, NDVI, PRI, SF, IRT$_{refDry}$, IRT$_{refWet}$, ZL6**
5						**T-12, ZL6**
6						
…						
17						

SSDRIP=Subsurface drip irrigation SDRIP= Surface drip irrigation

5 Big and Smart Data Management:

In agriculture and environmental measurement technology or nutritional science, there are many manufacturers of sensors, and each uses its own databases to manage the sensor data. As a result, combining the data retrieved from the various sensors is hardly possible.

The basic idea underlying this case study - big and smart data management - is to gather all the data into one database regardless of their source. For this purpose, the data are retrieved from their respective data sources and managed together in a single system. Thus, it is possible to visualise the parameters in one system and combine them in any way, providing several advantages for the user.

In this pilot action, a sensor system was purchased from METER Group. This system allows connecting up to six sensors to one data logger. The system also allows selecting various measurement parameters, probably the most important being the choice of the measurement interval. The data logger sends the sensor data via the mobile communications network to its own cloud data storage solution (ZENTRA Cloud), where the data can be visualised. However, as previously mentioned, only the data from this manufacturer can be analysed by using this approach. Furthermore, there are several restrictions; for example, users must register to the manufacturer's system.

This case study set up a FIWARE system to assess the possibility of analysing different sensors supplied by various manufacturers. In this system, a FIWARE Context Broker gathers the data from different sources. Regarding the data from the METER Group, the Context Broker collects the data via an API (application programming interface) of ZENTRA cloud. The sensor data are then handled by the FIWARE database, described later in this document. Since other manufacturers provide similar APIs, the collected data could also be included in the FIWARE system.

Furthermore, publicly available open-source data (for example, publicly available weather data or weather forecasts) can easily be integrated into the system. Thus, a common visualisation of sensor data from different sensor systems can be enabled, whereby mathematical operations with the sensor data are also supported. The system operator can assign different user rights and create multiple dashboards to visualise and analyse the data.

Deliverable D.T2.2.11: Test in environment, tech protocols and operational guidelines for case study 3

The big and smart data pilot action was established in Tata (Hungary) to initiate technological tryouts based on trans-open innovation involving agronomists, farmers, PF specialists, and external experts. In addition, two mini-projects were initiated within the small-scale precision farming projects to evaluate the microclimatic conditions of different irrigation strategies and terroirs. The main objective of this pilot action is to collect, handle, and share vineyard canopy microclimatic and plant physiological data.

6 Data loggers and sensors

Data loggers and sensors (Figure 5) were purchased from the METER Group (METER Group, Inc. USA).

6.1 ZL6 Data Logger

The solar-panel-powered ZL6 Data Logger serves as a data collection station for as many as six sensors. It is designed for a plug-and-play setup with all METER sensors, including the ATMOS weather sensors, TEROS soil moisture sensors, HYDROS water sensors, PHYTOS leaf sensors, and ECH2O soil moisture sensors.

For proper installation and configuration, it is necessary to download and run the ZENTRA Utility software (metergroup.com/zl6 -support) on a PC connected to ZL6 via USB cable. The data are transferred to ZENTRA Cloud via cellular connection under a yearly subscription.

Although Metergroup directly uses ZENTRA Cloud, the FIWARE data lake platform (managed by LCM) was used during the Transfarm project to visualise the data.

6.2 TEROS 12

TEROS 12 sensors are accurate tools used to monitor volumetric water content (VWC) and temperature and EC in soil and soilless substrates. The TEROS 12 determines VWC using capacitance/frequency-domain technology. The sensor uses a 70-MHz frequency, which minimises textural and salinity effects, making the TEROS 12 accurate in most mineral soils. The TEROS 12 uses a thermistor in the central needle to measure temperature and EC using a stainless-steel electrode array.

Two sets were purchased in coordination between LCM and MATE and installed in the three experimental plots (rainfed, surface drip-irrigated and subsurface drip-irrigated) at 30 and 60 cm depths.

6.3 ATMOS 41

The ATMOS 41 All-in-One Weather Station is designed to continually monitor the environmental variables, including all the standard weather measurements:

- Solar radiation
- Precipitation
- Air temperature
- Barometric pressure
- Vapor pressure
- Relative humidity
- Wind speed
- Wind direction
- Maximum wind gust
- Lightning strikes
- Lightning distance
- Tilt

6.4 NDVI/PRI Sensors

Two types of multispectral reflectance sensors were adopted in the pilot field experiment to monitor photosynthesis and the stress-related plant reflectance indices (NDVI and PRI).

Normalised Difference Vegetation Index (NDVI):

$$NDVI = (R_{810}-R_{650})/(R_{810}+R_{650})$$

Where:

R_{810} and R_{650} are the averages of the fractions of incident radiation reflected by the canopy surface at 810 and 650 nm, respectively.

Photochemical Reflectance Index (PRI):

$$PRI = (R_{532}-R_{570})/(R_{532}+R_{570})$$

Where:

R_{532} and R_{570} are the averages of the fractions of incident radiation reflected by the canopy surface at 532 and 570 nm, respectively.

Hemispherical sensors that capture the incident radiation and field stop sensors oriented to the neighbouring canopy walls, i.e. that capture the canopy reflectance (tuned to the specified wavelengths), were installed in the experimental vineyard to obtain the reflectance values at the wavelength bands designated in the formulas above.

Two sets of field stop sensors were installed, allowing the selected rows to be observed from both the SE and NW directions to analyse the morning and afternoon phenomena throughout the day.

6.5 Infrared Temperature Sensor

Infrared sensors were set up in the experimental vineyard to estimate the water relations of vine plants having different water supply by indirectly following the leaves' stomatal regulation. In this sense, one of the practical indices, the CWSI index, was calculated. Furthermore, to define an actual temperature scale, two temperature extremes were provided using an artificial "dry leaf surface" for T_{dry} and an inner canopy value as T_{wet}.

<u>Crop Water Stress Index (CWSI):</u>

$$CWSI = (T_{canopy}-T_{wet})/(T_{dry}-T_{wet})$$

Where:

T_{canopy} is the average temperature of the canopy surface, while T_{dry} and T_{wet} are the high and low extremes of the relative temperature scale, respectively, to calculate normalised stress indices.

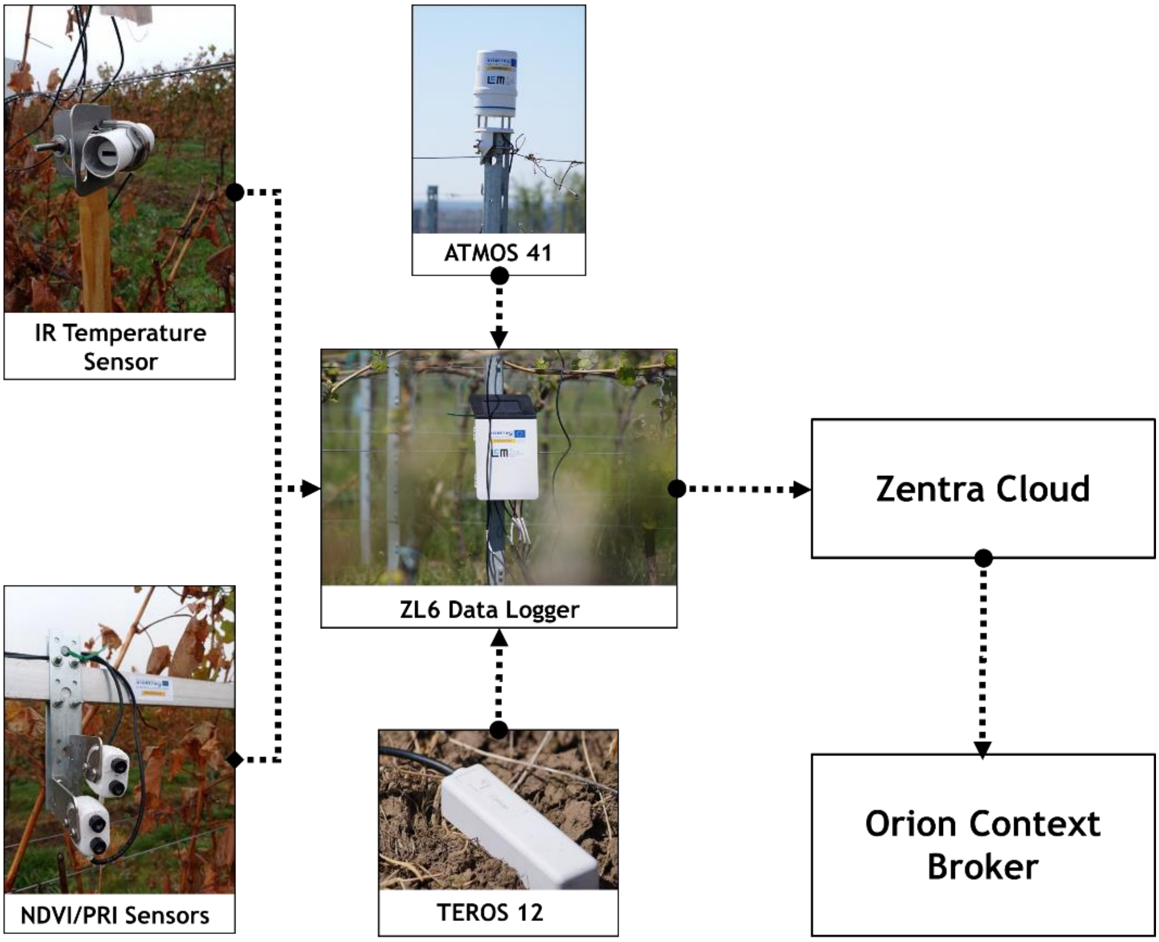

Figure 5: Sensor network of the case study 3.

7 Fiware Data Lake

The sensor data are retrieved from the Zentra Cloud using an API provided by METER Group and are then transferred to the FIWARE data lake.

In FIWARE, the sensor data are processed as time series, and all sensor data end up in a single database named etsensor.

For each record, the records in the database are:

- entity_id
- timestamp
- value
- units
- description

entity_id

The entity_id is made up of:

- serial number of the data logger
- port number, to which the sensor is connected at the data logger
- sensor ID (type of the sensor)
- measurement parameter

Hence, a specific sensor or sensor parameter can be chosen by filtering for the entity_id.

timestamp

The timestamp is the time stamp of when the measurement was taken.

value

The value is the measurement value, and its meaning depends on the sensor measurement type.

units

The units are inherent to the sensor itself.

description

The description is inherent to the sensor itself.

8 BigData Management

Sensor data are collected periodically through custom filters and fed to the FIWARE Orion Context Broker, which manages the context information, including updates, queries, registrations and subscriptions. The Orion Context Broker forwards the data to a QuantumLeap instance, which stores the time series in a CrateDB database. A Grafana web server can access and visualise the data from the CrateDB (Figure 6).

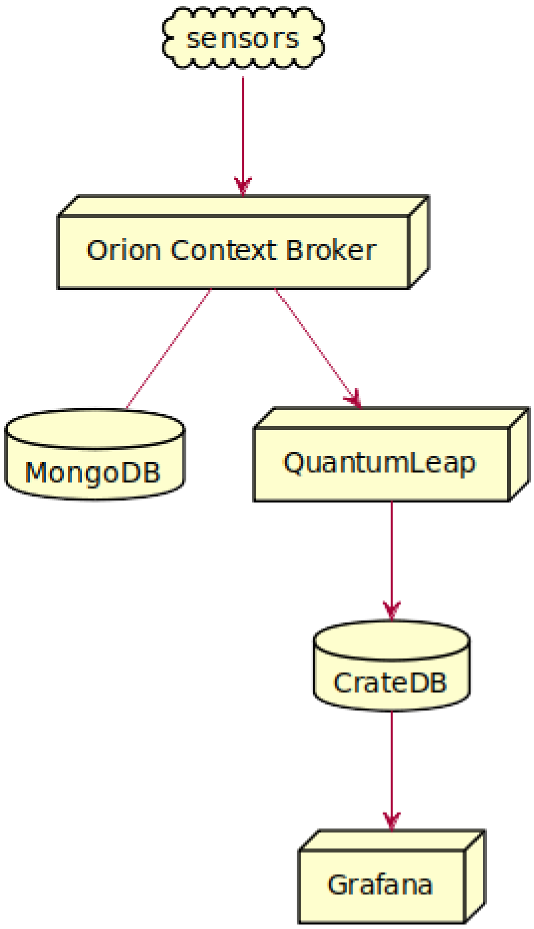

Figure 6: BigData management structure

9 Grafana (visualisation)

A Grafana web server is used to access and visualise the data from the CrateDB. (Figure 7) The farmers and other interested persons can log into the visualisation and monitor the parameters of interest. Several dashboards were created, each illustrating the relevant parameters for one type of irrigation at a specific location in the vineyard. The user can choose between the dashboards, and edit or create new dashboards. The parameters of the graphs, for example, the graph type or the time axis, can be changed, and new plots can be created. For example, combining the parameters of different irrigation systems in a plot can be very helpful when comparing the different types of irrigation.

Figure 7: Grafana web server platform

To be allowed to access the data, users have to register. User rights can be defined either as "viewer" or "editor". While a viewer can only access existing dashboards and plots, an editor can edit existing ones or generate new dashboards and graphs. Furthermore, it is possible to export sensor data in different formats (such as *.csv time series).

10 Results and Discussion

This pilot action aims to implement a smart data acquisition system in agriculture, allowing farmers to monitor and analyse relevant parameters (Figures 8-16) and act accordingly. For this purpose, microclimatic and plant physiological sensors were established in a vineyard featuring 3 different irrigation strategies (in-drip irrigated, sub-surface irrigated and rainfed rows). Teros 12, ATMOS 41, NDVI/PRI sensors and infrared temperature sensors were connected to ZL6 Data Loggers linked to Zentra Cloud, which is linked to Orion Context Broker. Primary data and calculated plant indices are visualised on the Grafana web server, where farmers, students and researchers can log in. With the help of the network, plant microclimate and physiology would be monitored, and farmers could act according to the data. For example, microclimatic data are essential to forecast the spread of fungal diseases.
Moreover, microclimatic data, particularly soil water content and plant temperature data, are necessary to plan optimal irrigation schedules and times. This new system would be useful to both farmers and technology providers, who could get information regarding the regional climatic conditions. Moreover, the collected data would be managed in a FIWARE data lake, an open-source platform. This data management

solution would benefit technology providers, too, allowing them to broaden and improve their range of services.

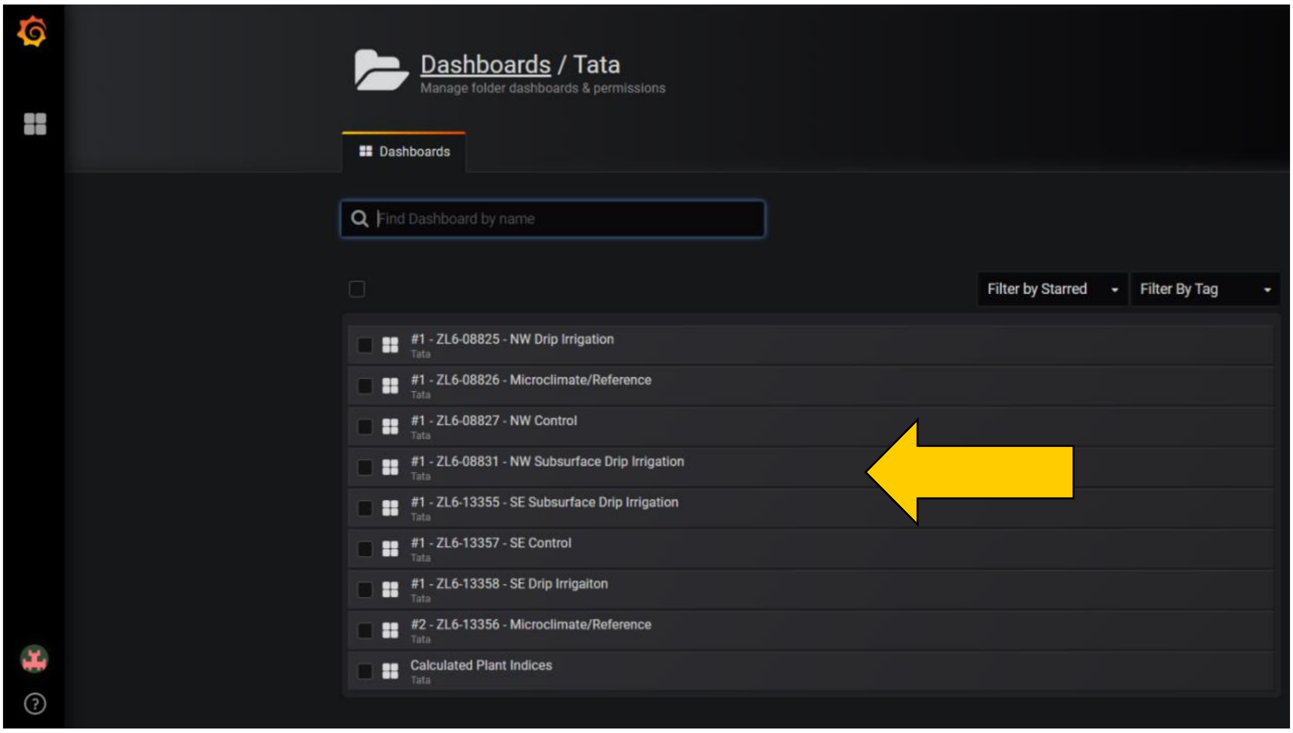

Figure 8: Sensor-network selection in the drip irrigated (NW side or SE side of the canopy), subsurface drip irrigated (NW side or SE side of the canopy), control, i.e. rainfed (NW side or SE side of the canopy), or reference microclimate and calculated plant indices

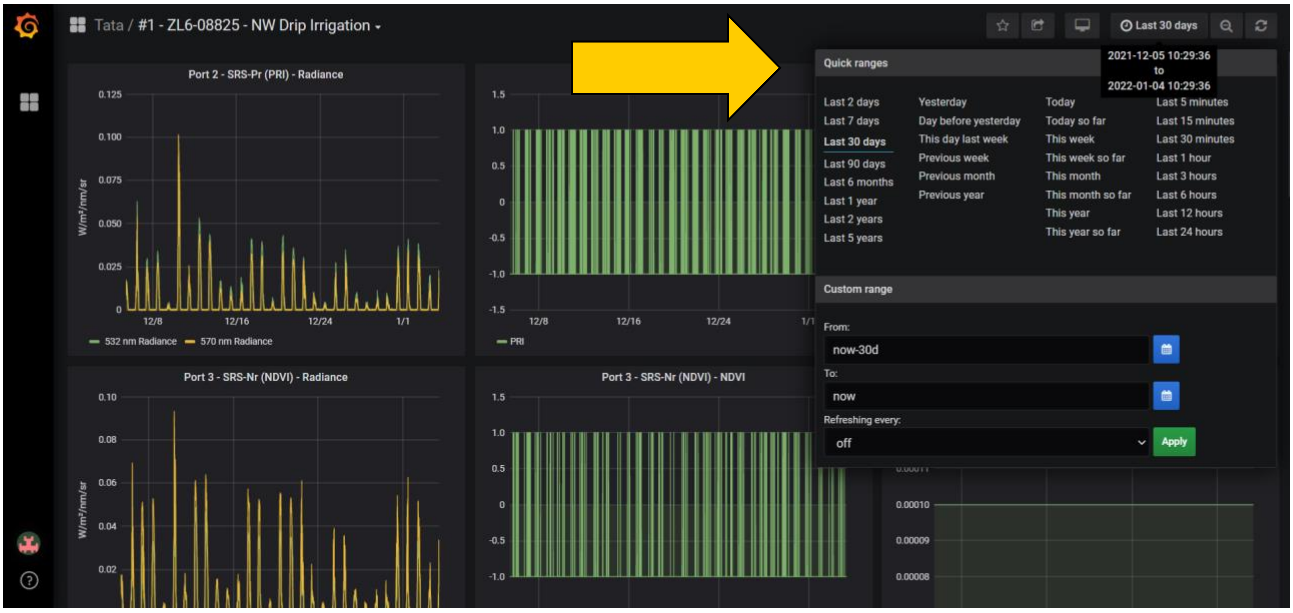

Figure 9: Range of time selection of the monitored parameters

Figure 10: Soil water content at 60 cm in the drip-irrigated row on the NW side of the canopy from 1st August to 31st August 2021. (arrow indicates the date of the irrigation)

Figure 11: Soil water content at 60 cm in the rainfed row from 1st August to 31st August 2021.

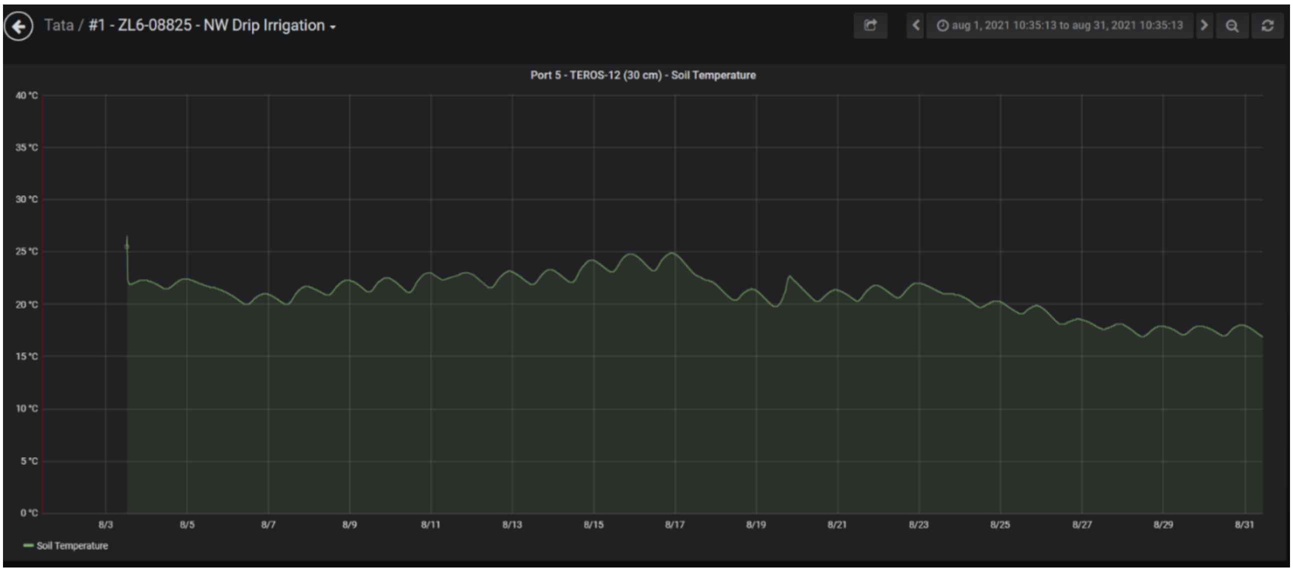

Figure 12: Soil temperature at 60 cm in the drip-irrigated row from 1st August to 31st August 2021.

Figure 13: Canopy temperature (body and target) of the drip irrigated canopy on the NW side of the row from 1st August to 31st August 2021.

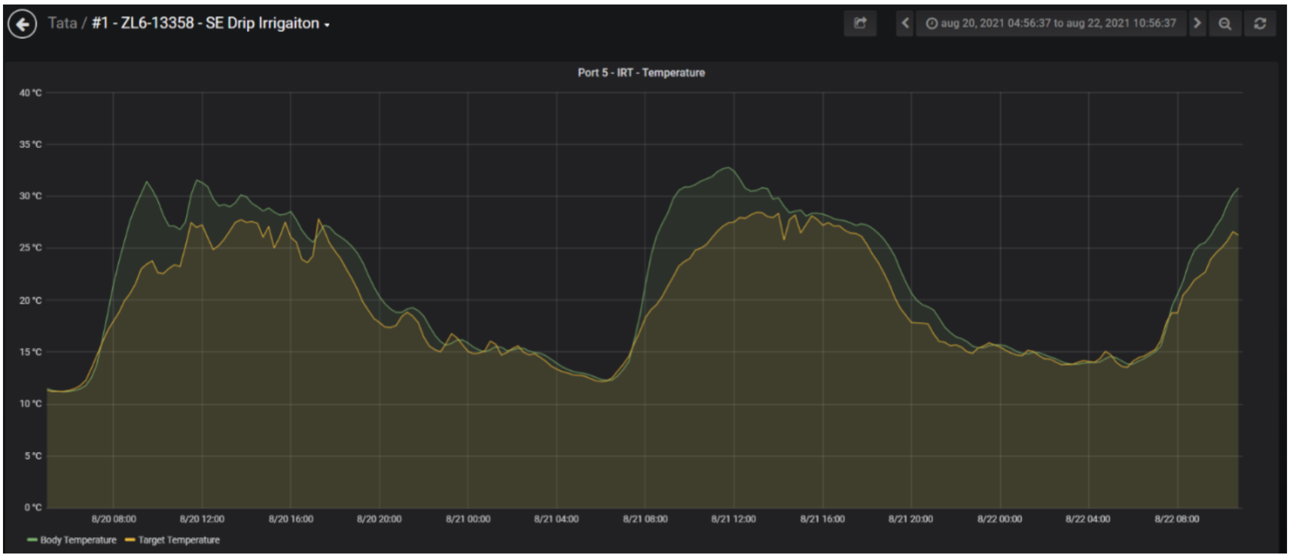

Figure 14: Canopy temperature (body and target) of the drip irrigated canopy on the SE side of the row from 20th August to 22nd August 2021.

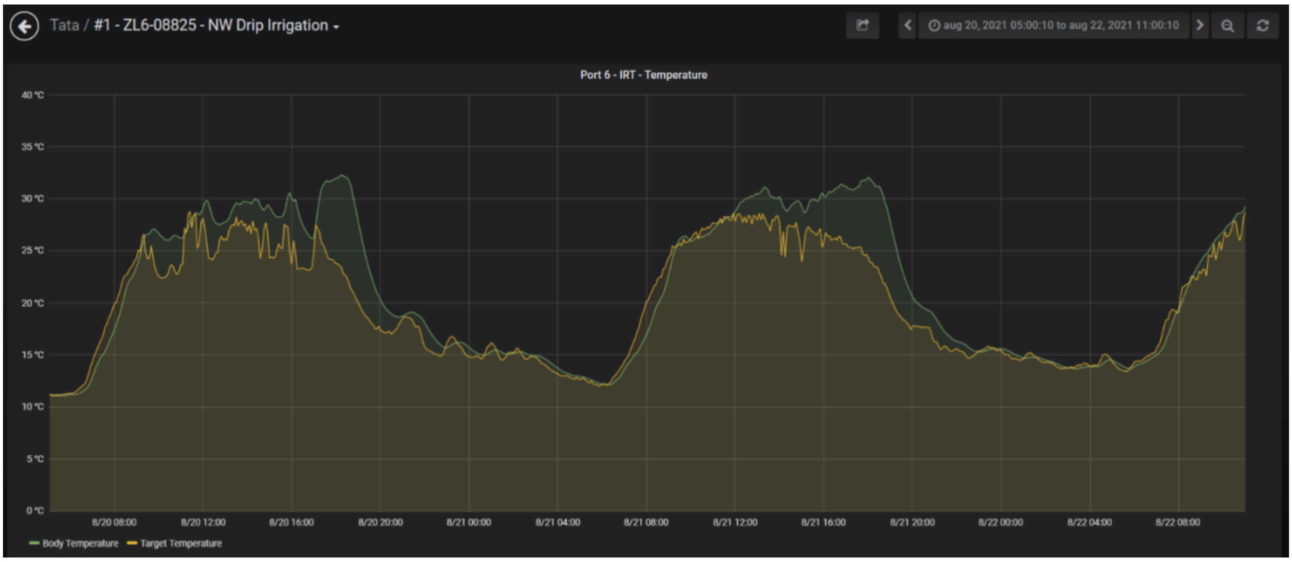

Figure 15: Canopy temperature (body and target) of the drip irrigated canopy on the SE side of the row from 20th August to 22nd August 2021.

Figure 16: Temperature differences of the N-SW row canopy sides (NW side and SE side of the canopy) indicated the maximum temperature, where the sun path caused differences.

11 A transnational approach to investigating new smart solutions

As reported by the worldwide trends, applications of precision farming technologies are increasing both in the agricultural and horticultural sectors. The main divisions where PF is most important are horticulture, fruit and vegetable growing, and viticulture.

Participants in the “Digital trends applied to the vine and wine sector”[1] online conference held by the International Organisation of Vine and Wine (OIV) emphasised that the leading digital trends in the vine and wine sector are IoT/sensorisation, artificial intelligence, satellite imagery/GIS, LIDA R, blockchain, e-label, e-certificate and smart storing. Within the field of sensorisation, vineyard meteorological monitoring (temperature, humidity, leaf surface moisture, soil water content, etc.) is the primary target to support the decision-making regarding proper irrigation, vineyard management and vine quality control. Several innovations have been introduced in the last decades to assist the viti-vinicultural sector. Among these, remote and proximal sensing are involved in the terroir evaluation, pest and disease management, yield prediction and nutrient supply. In addition, microclimatic evaluation of the vineyard aimed at monitoring the radiation, precipitation, humidity and temperature.

The transnational approach of this case study is supported by LCM GmbH (Austria), MATE and AgroIT (Hungary), with the contribution of the Mikóczy and Mikóczy Family Estate (Tata, Hungary). This pilot action features microclimatic and plant physiological sensors to monitor the grapevine status in the different terroirs and under different irrigation strategies. The sensors were selected based on MATE’s experience in agriculture/viticulture in collaboration with LCM’s experience in IoT and data management systems. They were installed in pre-determined locations within the vineyard. The sensors are connected to data loggers, which communicate their information to the sensor manufacturer’s cloud system.

A FIWARE system (hosted by LCM) was created, which is used for data collection and storage. The novelty of this approach is the ability to collect data from different data sources and gather them into a single collaborative system. Hence, sensor data from different data sources can be gathered into one data management system. Compared to current solutions, where the data provided by each sensor can only be visualised/analysed in the sensor supplier’s database, this yields several benefits for the end-user, for example, the possibility to optimise the irrigation strategy. Indeed, it would be easy to

[1] OIV (2021): Digital trends applied to the vine and wine sector. A comprehensive study on the digitalisation of the sector OIV Digital Transformation Observatory Hub. November 2021

combine the data from the soil moisture sensors with those provided by open-source weather forecasts.

The relevant data from the FIWARE database is made accessible via a Grafana web platform. Based on specifications defined by MATE, various dashboards were created to combine, visualise and analyse the sensor data. By using mathematical operations, user-defined parameters can also be calculated and illustrated. Different users can be created, and each user can be assigned different rights in the system. For example, specific dashboards can be made available only to selected users. The sensor data are then analysed by MATE, with the vineyard owner and other grape growers of the region also having access to the data.

12 Interaction among the members of the pilot action

In this pilot action, MATE provided the viti-vinicultural background of the study and designed the field experiments in two mini-projects to evaluate the effect of the different irrigation strategies and terroirs. Researchers of the MATE involved an external expert alongside the farm owner where the case study was carried out and who also actively participated in the experiment. In addition, MATE carried out literature data mining regarding the available remote sensing technologies. Based on the various experiences and international trends, two main factors were considered during the selection of the experimental plots. In the future, due to climate change, scheduled irrigation would be a necessary step to take in the Central-European wine regions. For this reason, we aimed to collect, handle and share data in this pilot action which would be beneficial, for example, to evaluate the soil and plant water status and physiology. The other mini-project aimed to evaluate the effect of the environmental factors on the microclimate, which is considered one of the main elements of the terroir concept. During the pilot action, MATE had ongoing discussions with the LCM, the external expert and the farm owner concerning the sensor settings and information provided by the online platform.

In this case study, LCM is responsible for creating and maintaining the data acquisition system. In particular, the selection of sensors, the specifications regarding the visualisation platform and the assignment of user rights were handled in close cooperation with MATE, as this partner has the required knowledge in the field of agriculture/viticulture, while LCM has an expertise in the field of IoT and data management systems. Furthermore, to be allowed to implement a solution “powered by FIWARE”, the regulations of the FIWARE foundation have to be met, requiring a certain degree of interaction with this partner. Another collaboration between LCM and the supplier of the sensor system (METER Group) was established to retrieve data from the sensor system.

Deliverable D.T2.3.1: Briefing papers of yield curve due to introduction of PF practices

13 Introduction

The cost of grapevine growing comprises several elements connected to canopy management, nutrient supply, weed control, disease and pest management, and harvest, among others. While a number of practices are fully or partially mechanised to decrease farming costs, others are still carried out by hand. Additional costs depend on the human capital and labour or mechanisation. For example, in the case of mechanisation, fuel and depreciation are additional costs. All new elements, such as an irrigation system, must be carefully considered.

The increasing worldwide water shortage is leading to a renewed emphasis on improved methods for irrigation scheduling and for water applications that make the best possible use of the water resources. This pilot experiment aimed to set up, test and refine a complex data collection system involving soil, plant and microclimate-related data using a standard web surface. Plant-base sensors that directly measure plant water status and the plant's response to the imposed conditions have an advantage over other irrigation scheduling methods as they provide an integrated measure of the plant’s response to the available soil moisture and the evaporative conditions (i.e. microclimate). A significant current limitation in applying plant-base sensors for commercial use in irrigation scheduling is that these techniques, like soil moisture and microclimate-based models, also do not provide a direct measure of the irrigation volume alone to be applied. Hence, plant-base sensing is commonly used in conjunction with soil moisture measurement equipment and/or a water balance approach. However, exact values for the proper irrigation volumes (i.e. when to switch off irrigation) can only be obtained by analysing the data (soil, plant and microclimate) collected during at least the previous two to three years at a given site, then leading to a site/crop/cultivar/management-specific irrigation scheduling. As of this, we are at the very beginning of exploiting the BigData pool. This process would surely lead to an optimised irrigation scheduling that would be refined from one year to the next via feedback from yield, composition and plant health results. The data collection, analysis and visualisation system applied in our model farm in Hungary would provide a solid basis for this working process to use a complex data pool of the soil-plant-microclimate continuum in constructing optimised irrigation scheduling.

14 Efficiency & sustainability of new PF devices

All plant-base sensors (i.e. NDVI, PRI and IRTemp sensors) of the network were positioned to observe the selected canopy wall from both sides, while the soil sensors were placed 30 and 60 cm deep within the three (rainfed, drip irrigated and subsurface drip-irrigated) experimental plots. In addition, the microclimate (ATMOS41) and the spectral (spherical NDVI and PRI) and temperature reference (T_{dry} and T_{wet}) sensors were installed in a nearby row.

All the sensors installed in our pilot experiment are passive equipment powered by solar panels ensuring full sustainability. The sensors and the data evaluation system together are highly efficient and sustainable.

15 Yields curve compared to historical data

The aim of this pilot experiment was to set up, test and refine a complex data collection network involving soil, plant and microclimate-related data by using a standard data web surface. As a result, we can conclude that now we are able to handle a multi-component digital data pool that can provide much more space and potential for the development of optimised irrigation scheduling compared to the limited opportunities the mere soil and microclimate-based but unorganised, ad hoc data collection offers currently in daily practice.

It has been proven that among the plant-base indices tested, the CWSI and the PRI indices were useful, while the NDVI index seemed unsuitable for the characterisation of short-term effects related to changes in plant water relations. Further analysis of the data from the two opposite directions provided by the sensors during the next consecutive growing seasons will allow us to select the best orientation and timing to plan the optimal irrigation scheduling.

16 Conclusion

This utilisation process leads to an optimised irrigation scheduling that will be refined from one year to the next, thanks to yield, composition and plant health results. The data collection, analysis and visualisation system applied in our model farm in Hungary provides a solid basis for this working process to use a complex data pool of the soil-plant-microclimate continuum in constructing optimised irrigation scheduling and sophisticated irrigation technologies. Other vine-growers of the region will also benefit from this technology innovation.