LIENNE–RASPILLE PROJECT:

IRRISALGESCH

EVALUATION OF THE WATER-SAVING POTENTIAL IN THE IRRIGATION OF A VINEYARD IN THE MUNICIPALITY OF SALGESCH USING AQUA4D® TECHNOLOGY

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1 Project Background

Switzerland may be the "water castle" of Europe, but the effects of global warming and the unpredictability of the climate are also being felt here. In the municipality of Salgesch (Valais), there is already an acute risk of a water shortage that will threaten local agricultural production in the coming years. The other communities in the region are also suffering from the water shortage. The "Lienne-Raspille" project, which involves eight municipalities in the region (Ayent, Icogne, Lens, Crans-Montana, Noble-Contrée, Sierre, Salgesch and Varen), aims to store more water in the existing Tseuzier dam and make it available via a network that still has to be completed across the municipalities. All research confirms that in the future we will still have the same amount of precipitation distributed over the year, but less in summer, more in winter and less in the form of snow. This fact is the crux of the issue. Snowmelt ends earlier, and water runoff in July-August-September will be greatly reduced if water is not stored and made available when it is needed most.

The Lienne-Raspille project has been submitted for approval and is currently being challenged by an NGO demanding that it include a water conservation component.

Partly due to this opposition, the municipality of Salgesch is currently implementing the "New Salgesch Irrigation" project, which aims to ensure the supply of water for the irrigation of cultivated areas.

This new system for supplying irrigation draws water from the plain with the help of pumps. Once the community is supplied with water from the Lienne-Raspille project, these pumps can be used as turbines and thus contribute to the generation of electricity.

It is obvious that the water savings demanded by the opposition to the Lienne-Raspille project can only be achieved by the users of the water themselves. These are primarily the municipalities and irrigation cooperatives. The largest consumers of water are the hydropower plants, which currently have between 90 and 120 million m^3 available per year. The demand for drinking water averages 4 million m^3 per year, which is even higher than the demand for agricultural irrigation (2.5 million m^3 per year). In dry years, agriculture requires more water (7 million m^3). It is estimated that this demand will increase to over 10 million m^3 of water by 2050. Water savings in agricultural irrigation therefore have a very important effect, as the significance of these savings is greatest in dry years.

How to future-proof water supplies in the Lienne-Raspille region

There are numerous research elements involved in this project, including those analyzing how water will flow after the disappearance of the Pleine Morte glacier. The National Research Project 61 on Sustainable Water Management (NRP 61) has conducted research on various aspects of this topic. In his summary, Prof. em. Dr. Rolf Weingartner, former scientific advisor for hydrology to the Federal Council of Switzerland, concludes: "If nothing is done, we are heading for a water shortage".

This imminent water shortage poses a significant economic threat to the communities of Salgesch and the surrounding area, as the income of these communities is largely based on agriculture, viticulture and the associated tourism. A water shortage would lead to major socio-economic problems.

Pilot project to demonstrate the achievable water savings in the project perimeter Lienne-Raspille

The municipality of Salgesch and the engineering firm Cordonier & Rey SA (which is in charge of the two projects "Lienne-Raspille" and "New irrigation of Salgesch") have decided to carry out a pilot project on a vineyard parcel in the municipality of Salgesch. This pilot project aims to show that water savings are possible in the irrigation of vineyards in Valais and what measures need to be taken to achieve this. The project makes it possible to demonstrate how agriculture can achieve significant water savings by integrating the latest best practices and technologies. It also demonstrates how the Lienne-Raspille project can achieve water savings through water users.

The idea arose in discussions with the Valais-based company AQUA4D, which offers a water treatment technology that can be used to save water for irrigation. This company brings not only its water treatment technology, but also its global know-how from projects carried out in other regions with the same issues, such as California or Chile, in synergy with other new technologies. This is how the IRRISALGESCH project was born.

With this project, the three partners (Municipality of Salgesch, Cordonier & Rey SA, AQUA4D) took part in the first PrixAlpiq and were awarded the first prize of 40,000 CHF, which financed a large part of this pilot project for the first trial year. This project "IrriSalgesch" aims to show that it is possible to save water with modern irrigation technologies. Already at the end of the first trial year, the interest of other municipalities in this project was confirmed. There are currently four ongoing projects to renew irrigation networks in the Lienne-Raspille area: Salgesch, Noble contrée (Venthône irrigation syndicate), Crans-Montana (Corin-Loc) and Lens.

The project involves the combination of the following irrigation technologies:

- Modern monitoring instruments for soil moisture and plant water stress in combination with remote controlled valves and automated irrigation;
- Irrigation with the newest-generation drip irrigation;
- Water treatment with AQUA4D® technology manufactured in Sierre, Valais.

The combination of these technologies has been estimated to potentially save more than 40% of the water used for irrigation compared to previous years.

Integrated water management for the benefit of upstream water availability.

With this project, the annual demand for irrigation water in Salgesch can be reduced from 436,000 m^3 to about 262,000 m^3. Today, the 8 municipalities involved in the "Lienne-Raspille" project need about 7 million m^3 of water per year for their total agricultural cultivated areas in dry years. So, with optimizations for all these communities, about 3 million m^3 of water can be saved. For the year 2050, the researchers estimate irrigation needs will be about 10.5 million m^3, so a 40% savings would equate to total savings of 4.2 million m^3 of water per year by 2050.

Put simply, the impact of this project could be astounding, and its success would have a clear signaling effect. Other neighboring communities would also want to follow suit and optimize their irrigation networks. Accordingly, the implementation of an integral water management project of this size is of national interest, as proven by the largest national research project in this field to date, NCCR 61.

Advantages for the ecosystem and the environment

Water conservation measures and reduced water demand will also benefit the flora and fauna in the waterways, with more water available upstream during the increasingly frequent droughts. The region's ecological footprint will also be reduced, as continued strong wine production will mean less wine needing to be imported from other regions of the world such as Australia or Chile.

Against this background, the IrriSalgesch project investigated the potential for irrigation water savings through AQUA4D® water treatment technology. The water savings through AQUA4D were determined by comparing two plots with drip irrigation, one with normal water and one with AQUA4D-treated water, where the amount of water was adjusted through monitoring to the exact needs of the vines.

2 Summary of the IrriSalgesch project

The aim of the project is to evaluate the irrigation water savings potential of the AQUA4D® water treatment technology.

For this purpose, a comparison is made between two plots of the same vineyard (identical in grape variety, age, environment, and soil). The vineyard is equipped with a drip irrigation system and the irrigation management is optimized with modern monitoring tools. The aim is to demonstrate the additional savings that can be achieved with AQUA4D® in addition to drip irrigation. The irrigation network is divided in two to individually control the water supply on the two plots, one of which is equipped with the AQUA4D® system. Three rows of vines between the two plots were not irrigated throughout the season and served as a control reference. The plots are designated as NT (irrigation with normal water), TT (irrigation with water treated with AQUA4D®) and CT (non-irrigated plot).

Real-time monitoring sensors were installed to track soil moisture and water stress status of the vines in the NT, TT and CT plots. Irrigation frequency and duration is controlled based on the information provided by these sensors, which allows optimization of irrigation according to the needs of the vines.

The goal of the TT test plot was to save an additional 20% of water on top of the savings from drip irrigation without compromising yield and production quality.

3 Glossary

- Lienne-Raspille Project: intercommunal and integral water management project involving the municipalities of Ayent, Icogne, Lens, Crans-Montana, Noble-Contrée, Sierre, Salgesch and Varen.
- New Irrigation of Salgesch Project: Project of the municipality of Salgesch. Renewal of the entire irrigation system.
- IrriSalgesch Project: Demonstration project for water optimization in a vineyard in Salgesch.

4 Materials and Methods

4.1 Plot characteristics

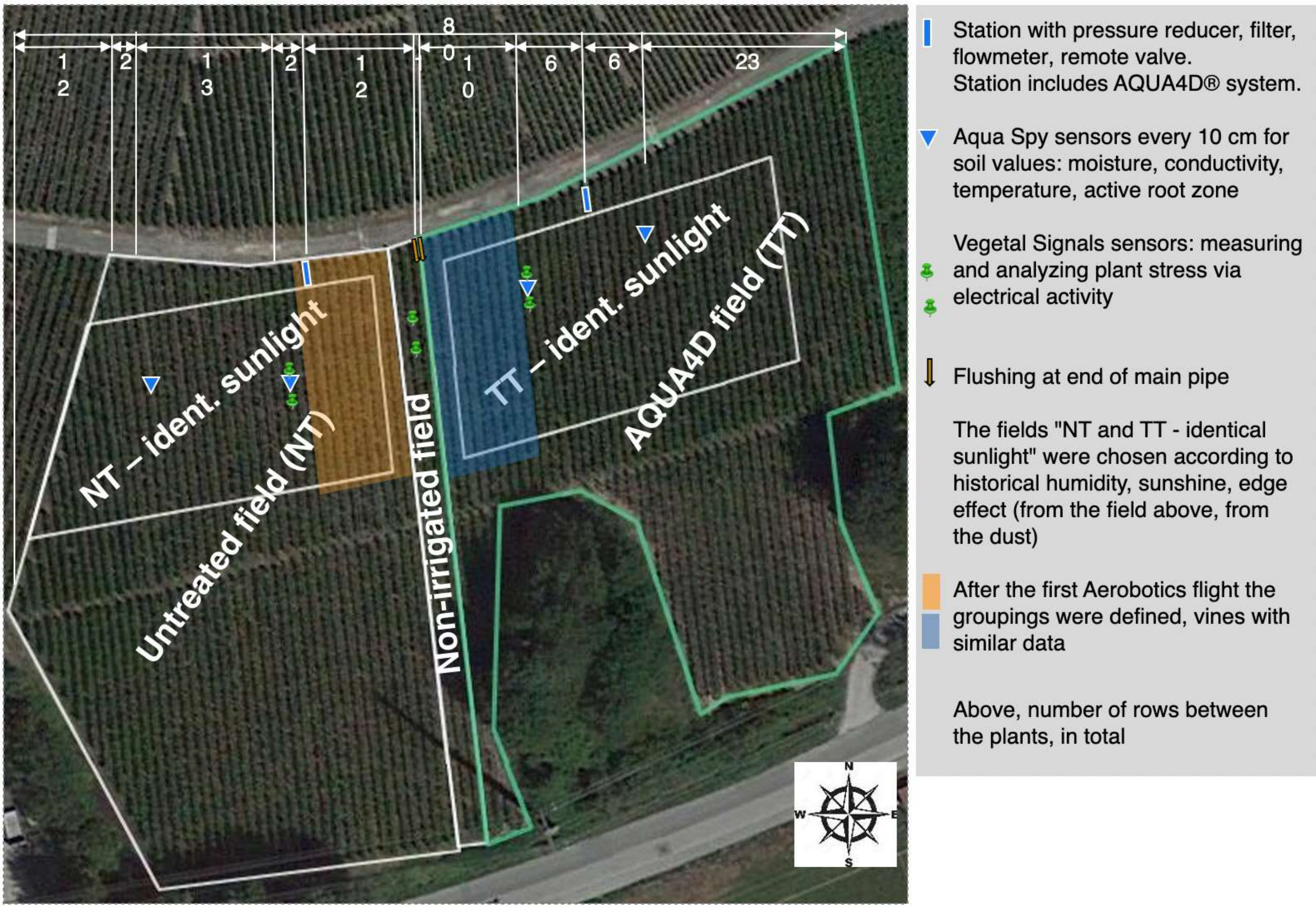
Grape variety	Pinot noir
Grafting rootstock	5BB
Year of planting	2010
Soil texture (More details in "Etude géopédologique des vignobles de Salgesch, Varen, Leuk, Agarn", see references)	Upper soil: 1716.1 /24R Large mud, calcareous soil, soils slightly redox, depth >150cm. Colluvial variants in concave lower slope and erosional settings. Thickened overburden from 1724/1725. Total limestone 40-60%. Average RUM 80-120 mm. Possible water circulation with high carbonate content, increasing susceptibility to chlorose. Lower soil: 9115.1/24 gr. Collusions on the lower slope, calcareous soil, slightly redoxic soil, depth between 100 and 150 cm. On "concrete soil" or moraine (less calcareous), very compact at depth.
Usable soil reserve, if not available (Root depth)	Root depth 8 to 10 m
Tillage	Mowing
Greening: if yes, width of greening	Spontaneous vegetation
Type of cultivation (IP, conventional, biodynamic)	IP
Row spacing	1.4 m
Distance between vines	0.70 m
Planting density	1.02 (plants/m2)
Foliage height	1.80 m
Foliage width	40% (Canopy coverage)
Orientation	South-facing
Pruning system	Simple Guyot pruning
Average yield	4.10 g/m2

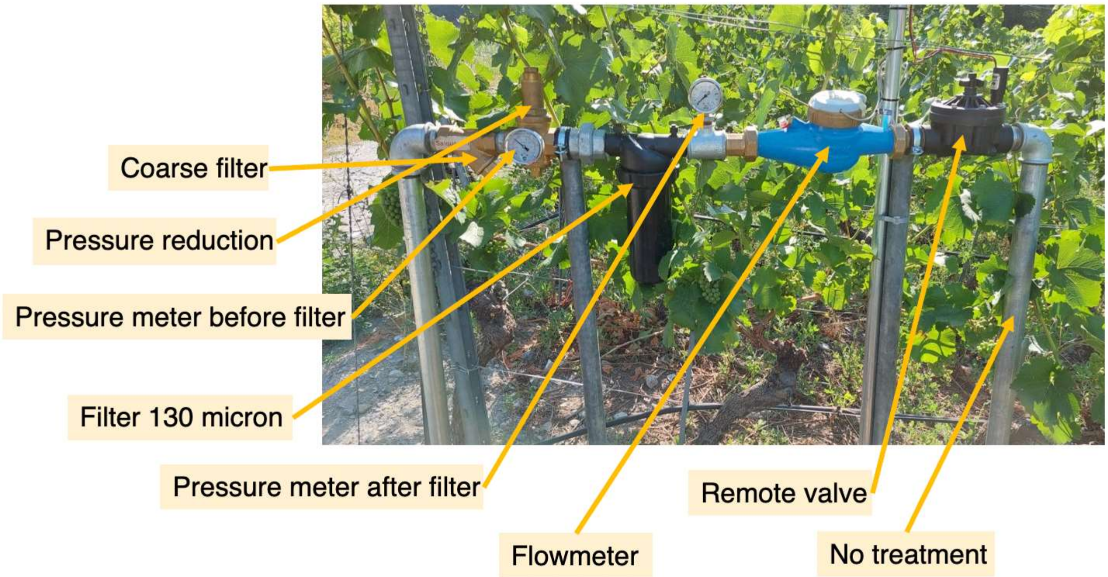
4.2 Installation of irrigation network

A network of drip tubing 16 mm - 75 cm - 2.3 l/h, kindly provided by the company Netafim, was installed by the Salgesch municipality in each row of vineyards.

The NT and TT irrigation networks are separate and independent. Each network has its own filter and automatic irrigation valve, which can be controlled with the Spherag app.

Experimental fields



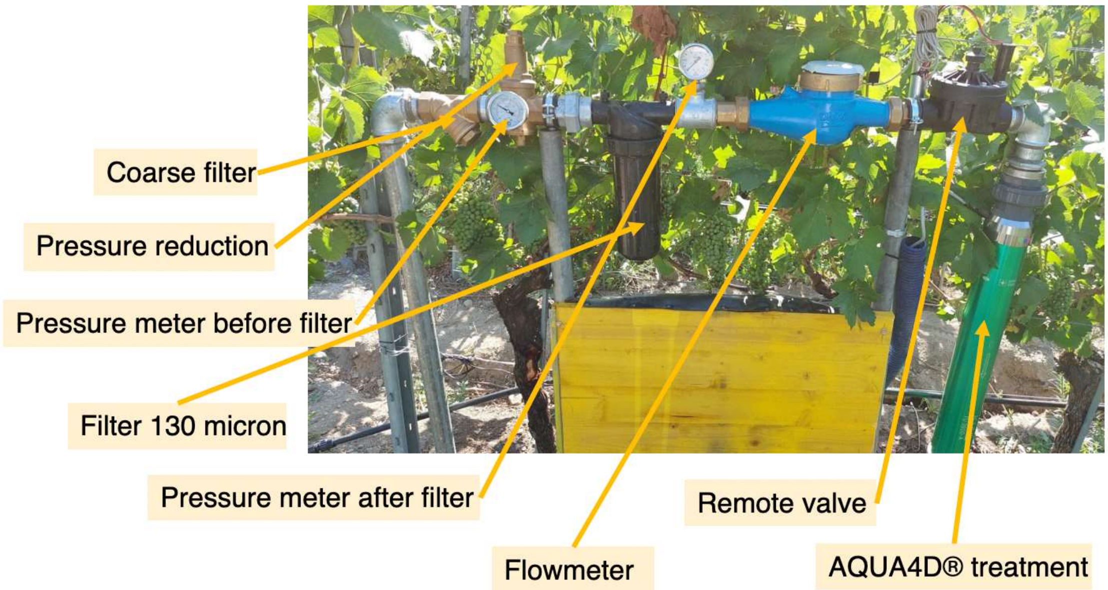


Irrigation system on NT + CT side

4.3 Installation of AQUA4D® system

The AQUA4D® treatment system was installed on plot TT after the automatic irrigation valve.

It is fed by a solar system installed at the edge of the plot.



Irrigation system on TT side

4.4 Agronomical monitoring

4.4.1 Soil moisture

AquaSpy probes were installed, 2x on the NT plot and 2x on the TT plot. The decision to install two probes on each side was made to ensure the reproducibility of the measurements obtained. The probes have sensors at 10 cm intervals, allowing the effects of irrigation cycles on soil moisture and precipitation to be tracked, allowing accurate scheduling of irrigation cycles. These probes use capacitive measurements, similar to the Sentek product often used in research.

Sensor TT East

Sensor NT East

Sensor TT West

Sensor NT West

Due to the stony nature of the soil, it was not always possible to place the probes at a depth of 120 cm, but the number of sensors in the soil, between 8 and 10, makes it possible to follow well the effects of irrigation and precipitation. The sensors above ground were taken out of service.

4.4.2 Monitoring of water status

Monitoring of water status was carried out by two methods: the use of Vegetal Signals sensors and measurements of stem water potential with a pressure chamber (Scholander pump).

A set of Vegetal Signals sensors was installed on each NT, TT and CT plot. The measurements of the leaf water potential with a pressure chamber were carried out on the vines facing the vines on which the Vegetal Signals sensors were installed.

 	
Top: Box that collects the various signals, records the data and passes it on. Bottom: A sensor for electrical signals	Right: Solar panel for power supply

4.4.3 Development of NDVI, NDRE, volume and canopy with drone imaging

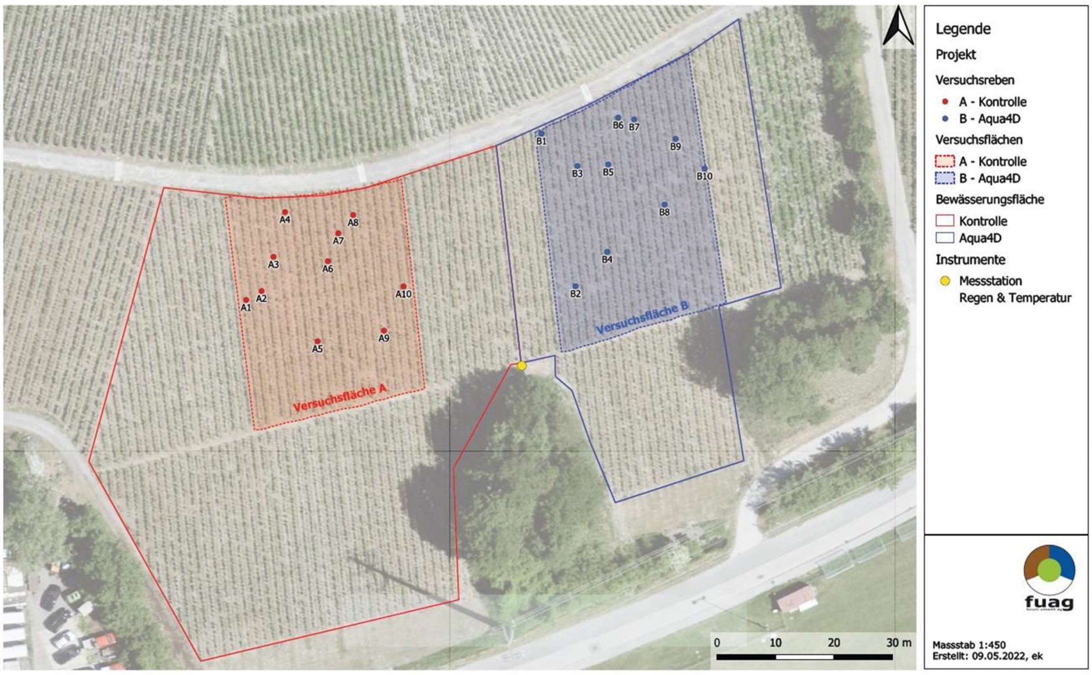
Two drone flights were performed. The collected data were processed by the Aerobotics company. This allowed to get an overview, but also to see for each vine the health, leaf cover, volume, etc. and their evolution during the season. The behavior of the NT, TT and CT plots was also compared.

The vineyard selected for the experiment has strong vegetative variations in the lower part due to groups of trees that influence the solar radiation. The upper part, which has the same solar radiation on both sides NT and TT, is under the influence of edge effects (road dust, etc.), so it seemed very important to select two comparison plots that are historically similar in vigor and soil moisture. By using historical satellite imagery showing moisture and vigor, two similar plots, one TT and one NT site, were identified before the first drone flight was conducted.

4.4.4 Detailed observation of vines’ phenological development in each sector

Sampling and phenological observations on the vines were carried out by the company FUAG (Visp) to evaluate and measure the development of the foliage, the grapes, the sugar content and the data of the phenological phases on a total of 20 vines. The behavior of the NT (9 vines), TT (10 vines) and CT (1 vine) plots could thus be compared.

The following text in this chapter 4.4.4 is an excerpt from the report "Field trial vine development with IrriSalgesch AQUA4D Project - Stand report trial monitoring - focus phenology - Visp, November 2022" (in German). The complete report can be found in Annex 1.



Plan for phenological monitoring by FUAG (area A (=NT) and B (TT)

Methodical objectives

Determination of experimental plots with comparable conditions in terms of shading, soil properties, slope or exposure and plant material. Monitoring of the development at the level of the overall situation from the plot to the individual plant.

Organization of the work:

AQUA4D

- Water consumption and weather conditions; continuous measurement.
- Evolution of site conditions (water balance of the soil); continuous measurement.
- Development of the plants’ water stress; continuous measurement
- Development of plant vitality plants based on aerial imaging.

FUAG

- Development of the phenology of the plants based on field recordings
- Development of the biomass of the grapes based on field recordings
- Development of grape quality (Oechsle scale) based on field recordings

Selection of vines

In one vineyard, one plot was drip irrigated with conventional water and one plot with technologically treated AQUA4D® water from. In February 2022, before the start of the growing season, two experimental Plots A and B were selected that were as similar as possible in size (approximately 1.142 m2) and characteristics such as shading, soil properties, and slope. Within these experimental plots, 10 vines were randomly selected and marked. An area not irrigated with the experimental A10 variety was established later, in May 2022, as an additional control plot (Fig. 1), i.e. the experimental arrangement was somewhat adjusted in coordination with the technical plan for the irrigation trial.

Field visits

The following phenology, biomass, and quality parameters were recorded every two weeks from April 21, 2022, to harvest on September 27, 2022, for the experimental vines:

- BBCH scale
- Number of bunches with flowers/grapes
- Measurement of bunch length
- Disease or discoloration or death of leaves/flowers/grapes.
- Measurement of Oechsle scale (sugar content of grapes).
- Photos of the trial vineyards

Irrigation on both plots was put into operation on July 14, 2022. At harvest, the °Oechsle degrees and the harvest weight per trial vine were additionally measured.

4.5 Meteorology

The meteorological aspects (temperature, rainfall, wind etc.) in the municipality of Salgesch were tracked on the Agrometeo website.

4.6 Work at the vineyard

Pruning and thinning were recorded to evaluate the effects of specific actions related to water status (data).

4.7 Irrigation cycles

The data and the amount in m^3 of each irrigation were recorded using the installed meters (1x on the NT side and 1x on the TT side) and the Spherag software, which allowed all irrigations to be programmed and tracked remotely. The first irrigation of the vines took place on July 14, when the vines were already in the generative phase.

4.8 Harvest

The yield and the quality of the grapes, as well as the degree of Oechsle, were measured for the NT, TT and CT plots.

5 Results and discussion

5.1 Layout of the trial fields

The design of the experimental field met the expectations, namely to have a comparison between TT, CT and NT plots. Regarding plot CT, which consisted of three non-irrigated rows between TT and NT plots, it seemed that there were border effects between these three rows and the neighboring irrigated rows.

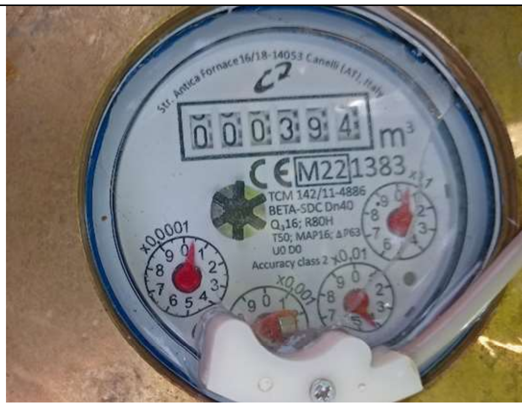
Nevertheless, a decrease in production yield was observed in this CT plot. (§ 5.3.7).

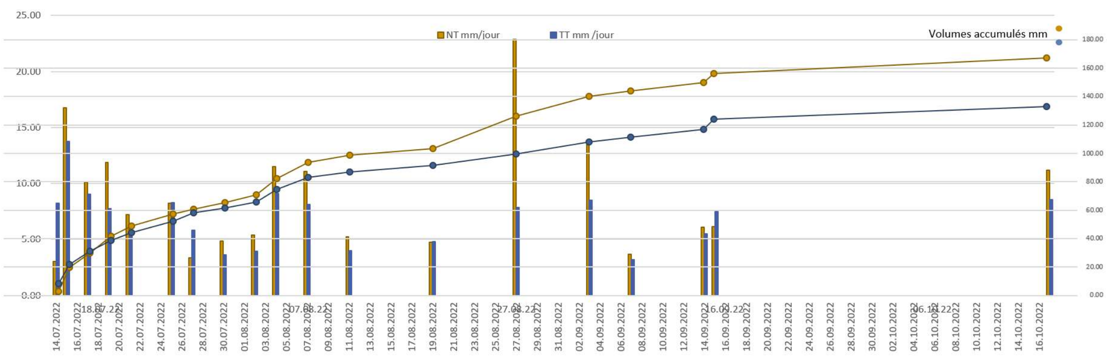
For future experiments, we recommend expanding the CT plot to 5 or more rows.

5.2 Irrigation carried out

Water was not available for irrigation during these periods: August 4-5, August 13-18, and August 23-28.

On several occasions, one or more filters were clogged and the scheduled irrigation did not yield the planned amounts. The differences were corrected in the next irrigation cycle or with separate irrigation. In the first two weeks, the online transmission of the water quantities was not correct, which led to the fact that initially a little too much was irrigated on both fields.

 Water counter NT – 27.09.2022	 Water counter TT – 27.09.2022



Date	NT mm/jour	TT mm /jour	Date	NT mm cumulé	TT mm cumulé
14.07.2022	2.7	7.2	14.07.22	2.7	7.2
15.07.2022	14.7	12.1	15.07.22	17.3	19.3
17.07.2022	8.9	8.0	17.07.22	26.2	27.3
19.07.2022	10.4	6.8	19.07.22	36.6	34.1
21.07.2022	6.3	4.6	21.07.22	43.0	38.7
25.07.2022	7.2	7.3	25.07.22	50.2	46.0
27.07.2022	2.9	5.1	27.07.22	53.2	51.1
30.07.2022	4.3	3.2	30.07.22	57.4	54.3
02.08.2022	4.7	3.5	02.08.22	62.2	57.7
04.08.2022	10.1	8.0	04.08.22	72.3	65.7
07.08.2022	9.7	7.1	07.08.22	82.0	72.8
11.08.2022	4.6	3.5	11.08.22	86.6	76.4
19.08.2022	4.2	4.2	19.08.22	90.8	80.6
27.08.2022	20.1	6.9	27.08.22	110.8	87.5
03.09.2022	12.0	7.5	03.09.22	122.8	94.9
07.09.2022	3.2	2.8	07.09.22	126.0	97.8
14.09.2022	5.4	4.8	14.09.22	131.4	102.6
15.09.2022	5.4	4.6	15.09.22	136.8	107.2
17.10.2022	9.8	7.5	17.10.22	146.6	114.7
	147	115			
	100%	-21.8%			
Vol total m3	568.34	421.60			
Surface m2	3877	3677			

The irrigation system worked well. For future experiments, taking into account the problems encountered, we still want to optimize this plan in two details in the second year:

- Install self-cleaning fine filters upstream of the irrigation system to prevent its clogging and the one ofdrippers, which negatively affect irrigation cycles
- Install manual valves at the end of each line to facilitate periodic flushing of drip lines.

Water consumption in relation to the total area of Salgesch

It is interesting to compare the amount consumed during the year for the whole area of Salgesch, 200 ha (Annex 2), with the consumption of the experimental plots NT and TT. For a comparison, we only have the gross areas available.

This comparison can only be an indicator, since the type of irrigation, the cropping density and the soils differ greatly.

Consumption of Salgesch area of 200 ha in total:	384,226 m3	192 mm	100%
Consumption of NT area(drip):	568 m3	147 mm	-24%
Consumption of TT area:	422 m3	115 mm	-40%

5.3 Agronomical monitoring

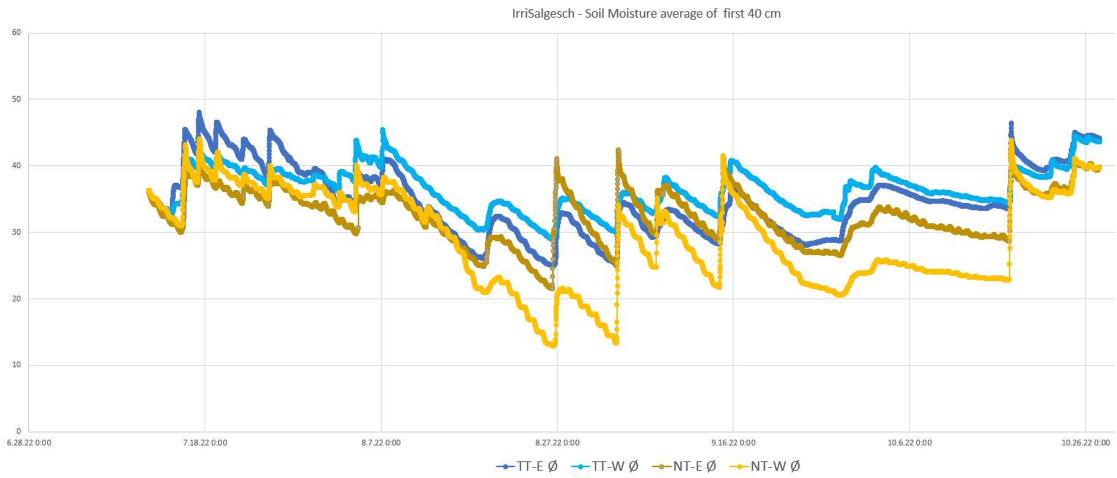
5.3.1 Soil moisture

Soil moisture monitoring with the AquaSpy probes worked well, allowing the following observations to be made:

- Moisture profile over all soil levels: to what degree did water penetrate after irrigation cycles and precipitation.
- A comparison of the NT and TT fields, a comparison of the dynamics of water ingress, the speed of drying of the soil. After thunderstorms, it was possible to see if they had a useful effect to moisten the soil and then to anticipate the frequency and duration of irrigation cycles.
- However, this type of measurement has a problem with self-calibration by the algorithms of their software. This problem had already occurred in another research project with the Universidad de Castilla-La Mancha in Spain. The calibration problem then occurred with both the AquaSpy and Sentek products, and is surmised to be related to the type of soil.
- The soil dries more quickly after each irrigation cycle on the NT side than on the TT side.

In the following graph, the moisture starting point for all four sensors was calibrated to the same moisture level on their startup date of July 14, 2022. The soil type at all four measurement points is identical. When the moisture probes were installed, it was verified that the soil texture and moisture were consistent between plots TT and NT, which was consistent with what was indicated on the map. Nevertheless, the texture of this soil type with relatively large stones may have an influence on the sensors locally, at certain levels.

Without this calibration, the moisture data do not correlate with the other monitoring data, especially plant stress, which was measured continuously with the Vegetal Signals sensors and three times during the experimental period with the pressure chamber.

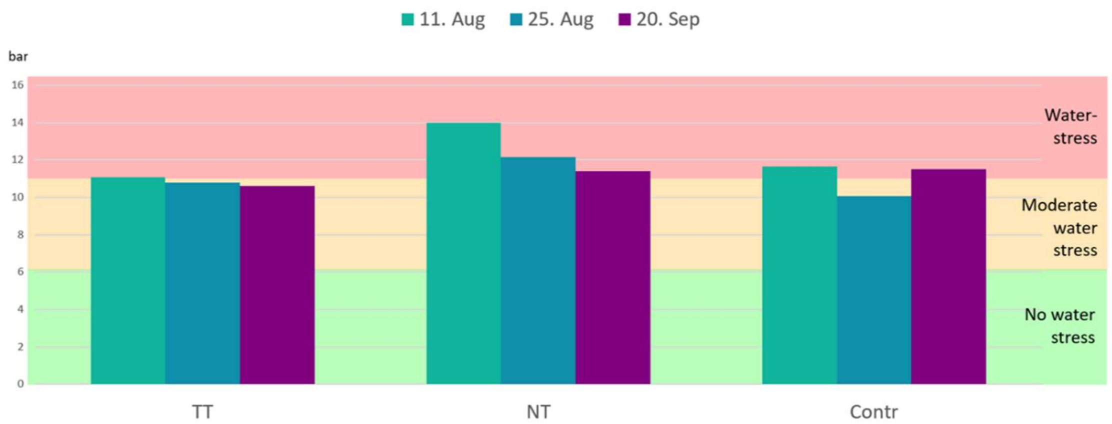


IrriSalgesch – Soil moisture up to first 40 cm

5.3.2 Monitoring of water stress with pressure chamber

It was agreed between the project partners to keep the vines in a light water stress condition and to ensure that they were not over-irrigated. Thus, the NT and TT plots were kept in a state of moderate lack of water throughout the irrigation season.

The measurements of water stress with the pressure chamber were performed three times during the watering period. The results of the measurements on the vines on the NT side with values above 11 bar each confirmed that the NT plot was under water stress. The vines on the TT side, irrigated with 20% less water, never exceeded the threshold for "moderate water deficit" (P < 11 bar). It was also observed that the vines on the CT plot (non-irrigated) were in moderate water deficit when measured on August 25.



5.3.3 Monitoring of water stress with Vegetal Signals sensors

Monitoring plant stress with Vegetal Signals sensors and being able to track it in real time via an app enabled predictive planning of irrigation cycles. The technology proved to be an interesting tool for managing irrigation, ideally in combination with the sensors providing real-time insight into soil moisture.

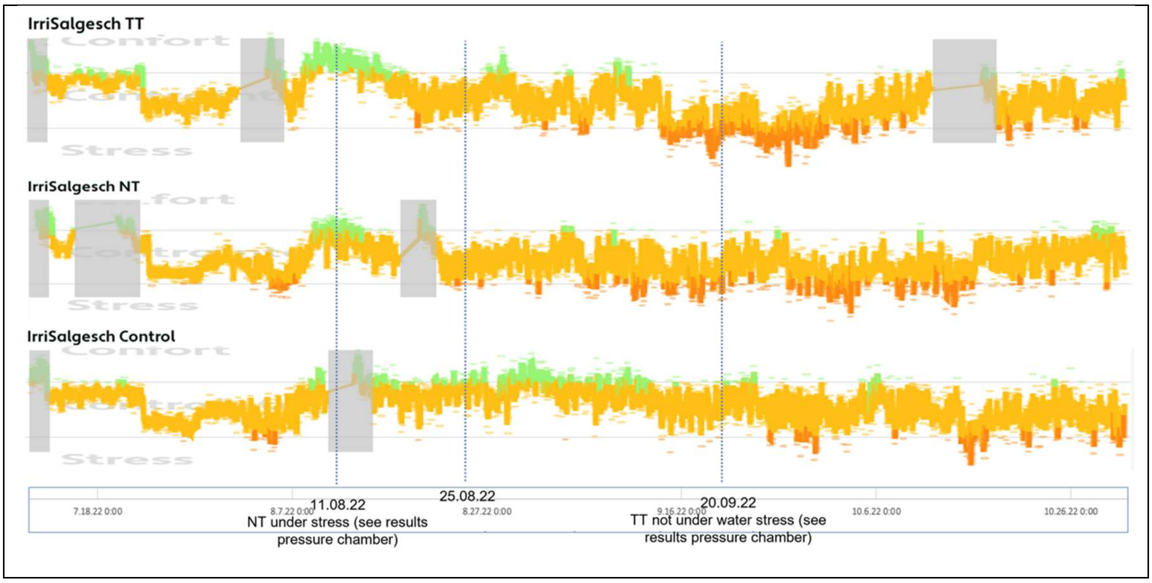
The final results will be included in a report by Vegetal Signals and published shortly. In the table below, some of the data is missing because it could not be sent live (over the Lora network). Nevertheless, the data were stored locally and retrieved at the end of the season. Each time the data transmission is interrupted, the system performs a new calibration, which takes 48 hours. For this reason, these areas are currently covered in gray.

On the curves, the following can already be observed:

- Until the end of July, the three curves TT, CT and NT were very similar.
- In August, the CT plot had the least stress. This was during the period when Salgesch had no water available for irrigation, for several days at different times of the month, while the plants used to irrigation cycles showed more stress. However, harvest data showed that the non-irrigated plants produced fewer grapes than the TT and NT plots.
- The TT plants had less stress than the NT plants in August.
- Starting in mid-September, the TT plot was in the stress zone several times. From this time on, the Vegetal Signals probe measurements did not agree with the pressure chamber measurements.

The final report from Vegetal Signals must be awaited for the final interpretation of this data. The measurements with the pressure chamber are used to calibrate their measurements and will have an influence on the final results.

The following diagram integrates the three time points of the measurements with the pressure pump.



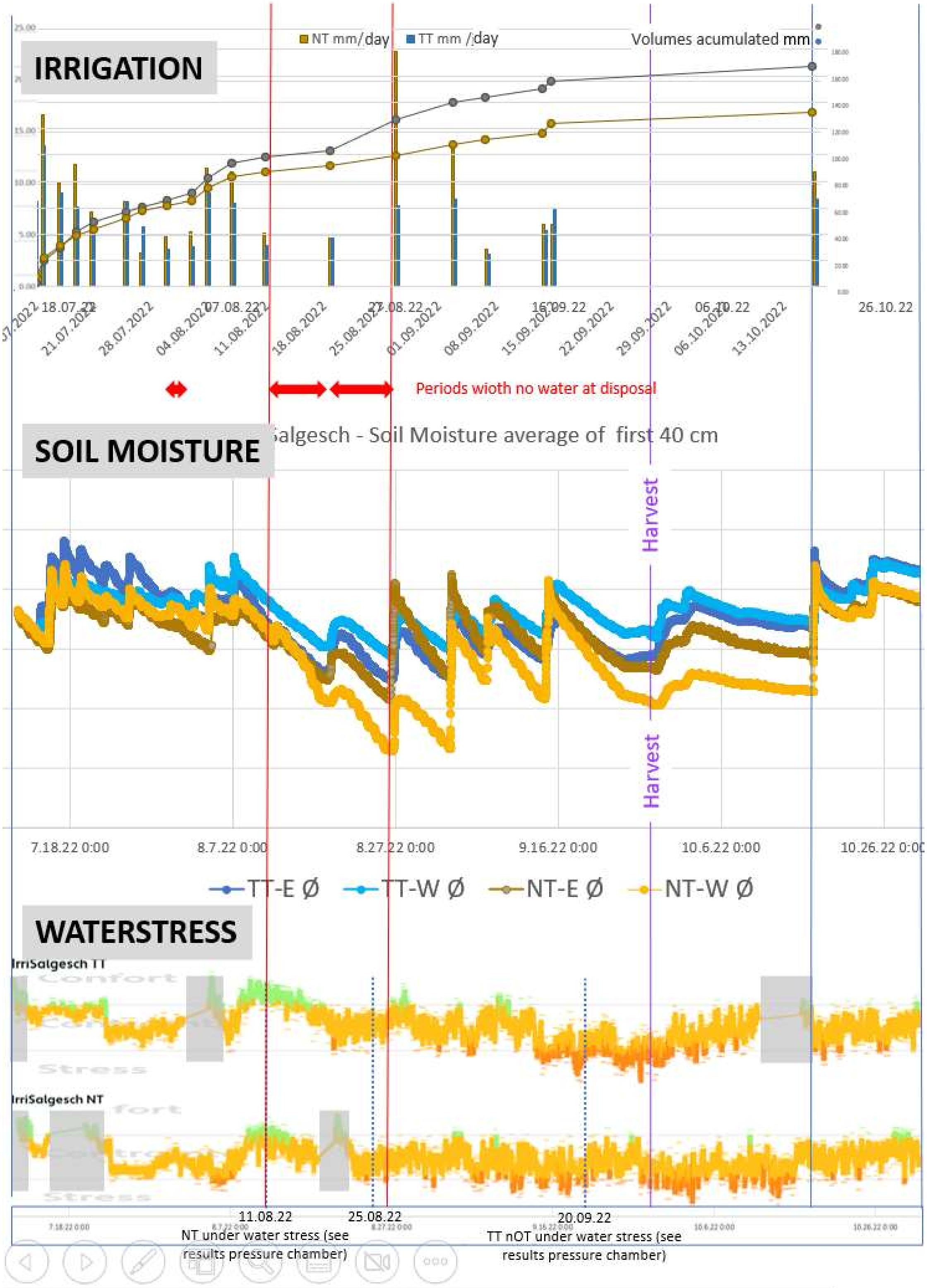
5.3.4 Irrigation, soil moisture and water stress combined in one graphic

In the second half of August, water was not available for irrigation. During this period, it could be observed that the soil on the NT side became dry faster than on the TT side. In September, this tendency was confirmed after each irrigation cycle.

Throughout the period from mid-August to harvest at the end of September, it can be observed that the NT plot was under higher stress compared to the TT plot, even though 20% less water was supplied for irrigation.

After harvest, the NT plot continued to be under higher water stress than the TT plot.

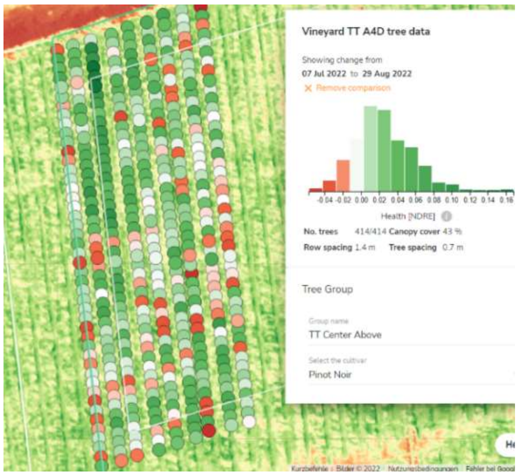
(Graphs on following page)


IRRIGATION
NT mm/day
TT mm /day
Volumes acumulated mm
18.07.22
07.08.22
27.08.22
16.09.22
06.10.22
26.10.22
Periods wioth no water at disposal
SOIL MOISTURE
Salgesch - Soil Moisture average of first 40 cm
Harvest
Harvest
7.18.22 0:00
8.7.22 0:00
8.27.22 0:00
9.16.22 0:00
10.6.22 0:00
10.26.22 0:00
TT-E Ø
TT-W Ø
NT-E Ø
NT-W Ø
WATERSTRESS
IrriSalgesch TT
IrriSalgesch NT
11.08.22
NT under water stress (see results pressure chamber)
25.08.22
20.09.22
TT nOT under water stress (see results pressure chamber)

5.3.5 Development of NDVI, NDRE, volume, and canopy with drone imaging

Results from second flight

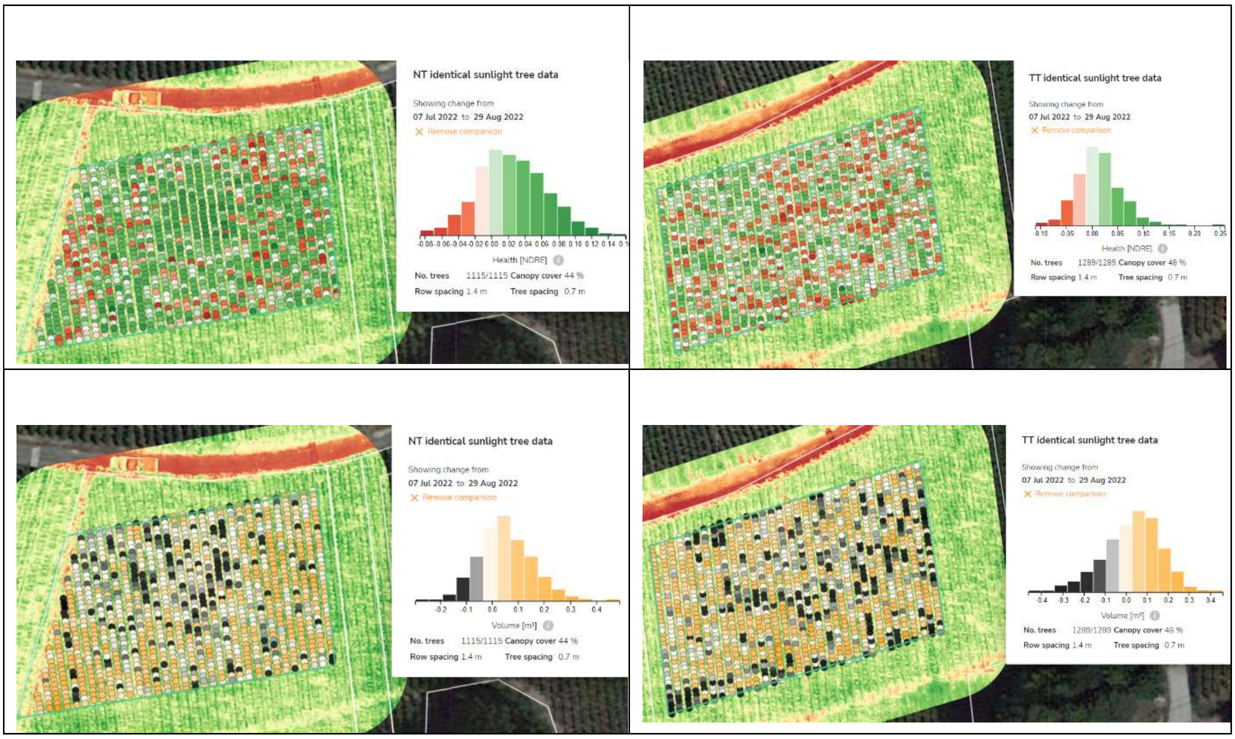
After the second flight, performed on 29/08/22, the development of the vines in plots TT, NT and CT was compared between 07/07/22 and 29/08/22. It was possible to make this comparison on the Aerobotics platform both visually and with the numerical data for each plot and sub-plot, in order to quantify the differences. The first comparison was made between the groups of "center above" vines, which had fairly identical values in the first flight on 07/07/22.



orchard_name	flight_date	tree_group	tree_health	tree_vigor	tree_area_sqm	tree_width_m	tree_volume_cb
Vineyard NT	07.07.2022	NT center above	0.36	0.73	0.46	0.76	0.20
	29.08.2022		0.35	0.75	0.45	0.76	0.24
	NT development 7.7. to 29.8.22		*-1.4%*	*2.7%*	*-0.3%*	*-0.1%*	*22.4%*
Vineyard TT A4D	07.07.2022	TT Center Above	0.34	0.72	0.45	0.76	0.20
	29.08.2022		0.37	0.78	0.52	0.81	0.30
	TT development 7.7. to 29.8.22		*7.2%*	*8.5%*	*13.9%*	*6.4%*	*47.1%*

The comparative analysis of the evolution of these groups shows a better health evolution (+7% versus -1%) and a better evolution of the volume (+47% versus +22%) on the TT side.

The following graphs and tables show the comparison between the selected group of vines before the first drone flight.

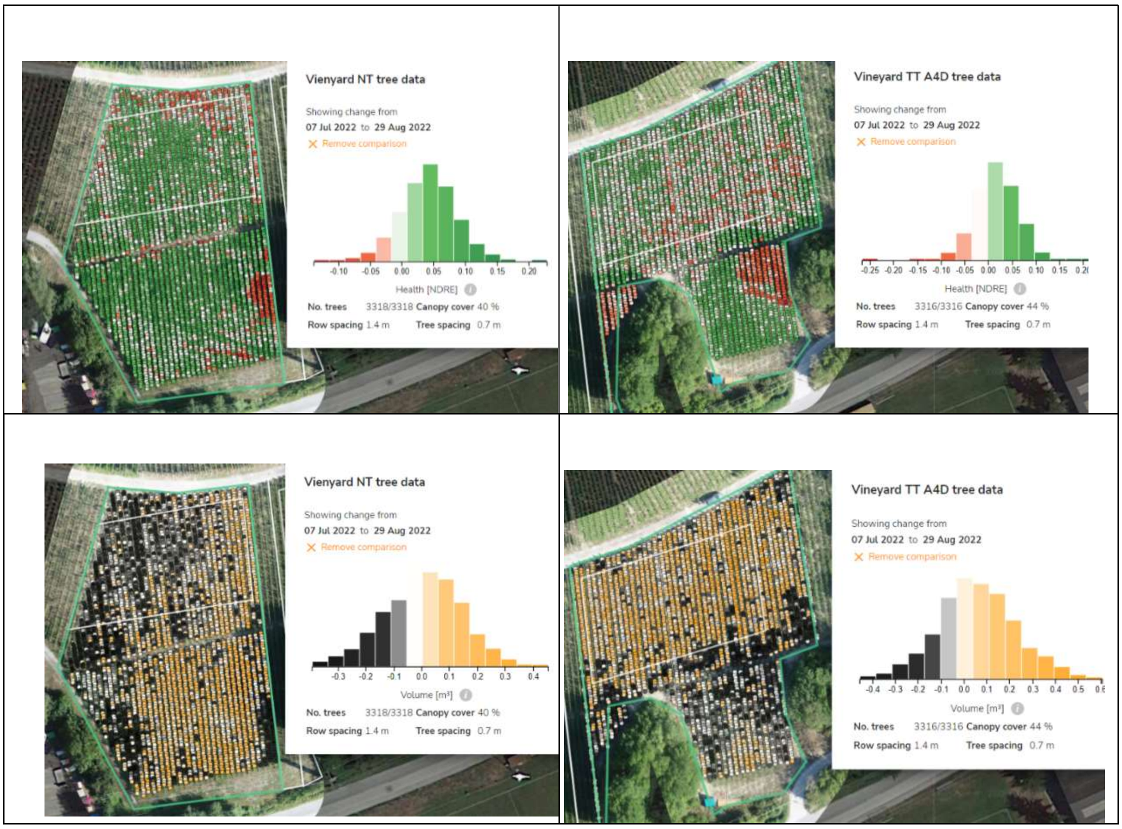


orchard_name	flight_date	tree_health	tree_vigor	tree_area_sqm	tree_width_m	tree_volume_cb
NT identical sunlight	07.07.2022	0.30	0.68	0.46	0.76	0.20
	29.08.2022	0.33	0.74	0.51	0.81	0.25
NT development 7.7. to 29.8.22		*8.0%*	*9.9%*	*12.5%*	*5.7%*	*24.6%*
TT identical sunlight	07.07.2022	0.35	0.76	0.46	0.76	0.29
	29.08.2022	0.36	0.78	0.50	0.80	0.32
TT development 7.7. to 29.8.22		*3.6%*	*2.3%*	*10.2%*	*4.6%*	*10.8%*

In these compared groups, the specific situation described in Annex 3 must be taken into account. With the lower starting point, the NT side evolves to normal volumes and health states.

In percentage terms, the evolution of the NT side is higher for both health (8% vs. 4%) and volume (25% vs. 11%).

With the data collected from the drones, it is also interesting to compare the evolution of the entire area treated with AQUA4D (TT) with the NT side, including the underlying fields, which have completely different conditions, as described in Section 4.4.3.

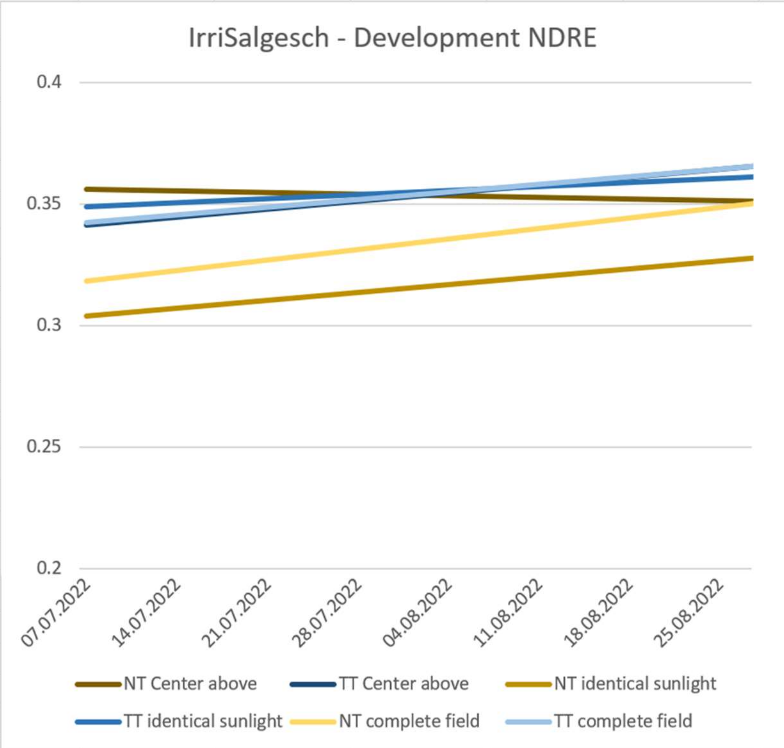


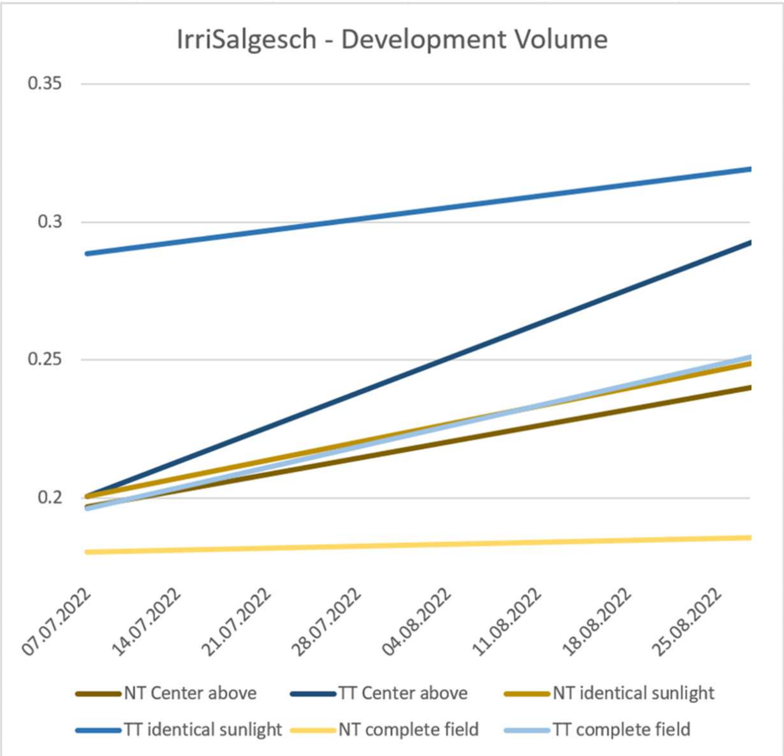
orchard_name	orchard_	flight_date	tree_health	tree_vigor	tree_area_sqm	tree_width_m	tree_volume_cb
Vineyard NT		07.07.2022	0.32	0.72	0.46	0.76	0.18
		29.08.2022	0.36	0.77	0.45	0.76	0.19
NT development 7.7. to 29.8.22			*12.9%*	*7.5%*	*-0.2%*	*-0.1%*	*3.0%*
Vineyard TT A4D		07.07.2022	0.34	0.73	0.45	0.76	0.20
		29.08.2022	0.36	0.77	0.47	0.76	0.25
TT development 7.7. to 29.8.22			*5.0%*	*5.7%*	*2.3%*	*0.5%*	*28.7%*

The images confirm that the lower part of the plot, with the large differences in solar radiation and access to groundwater, continues to cause a large difference in the development of health and volume.

Nevertheless, the difference in volume development of TT vines seems to be significant (29% vs. 3%) - it remains to be seen if this will be confirmed in 2023.

To see a trend in the development, the following graph summarizes the three comparison groups NT and TT in NDRE (health) and volume in m3.





In the merged graph, NDRE (health) and volume, one can observe the following.

- The development of the TT curves is more homogeneous than that of the NT curves.

- The differences in the evolution are greater on the NT side; an NDRE curve shows a negative evolution.

In conclusion, the data obtained with Aerobotics confirm that the TT side maintains at least the same quality (health) and volume as the NT side with 20% less irrigated water.

Additional information:

Annex 3 contains:

- The process of identifying two groups of vineyards with historically similar soil moisture and plant vigor.

- The process of identifying the NT and TT groups of vines, which are very similar in health, vigor and volume, after the first drone flight that took place before the start of the experiment.

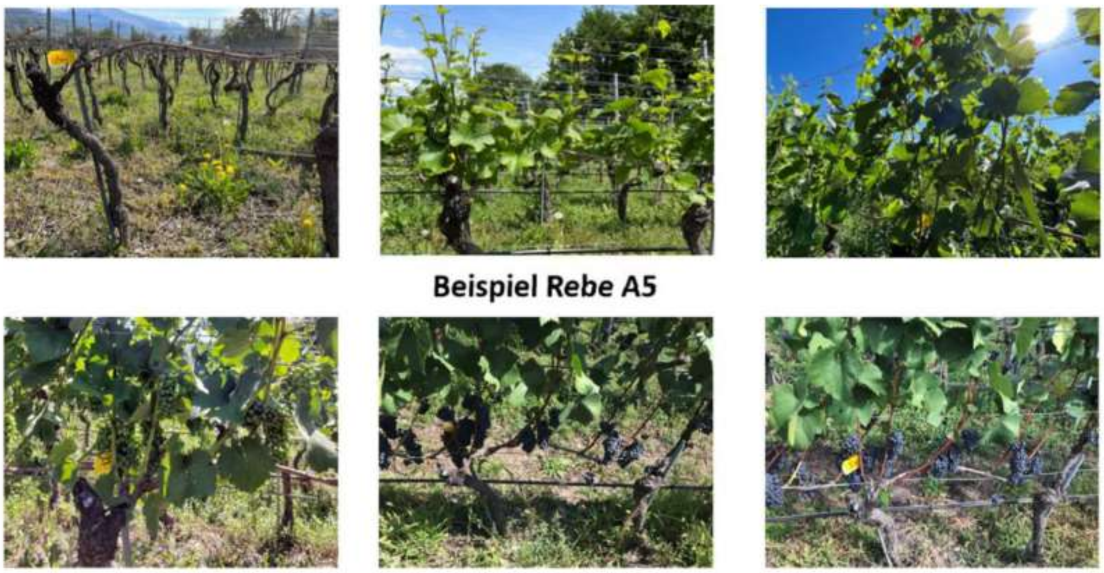
5.3.6 Results of the phenological development of the vines in each sector

The following chapter is an excerpt from the report "Field trial vine development with IrriSalgesch AQUA4D Project - Stand report trial monitoring - focus phenology - Visp, November 2022".

The complete report can be found in Annex 1 (in German).

Phenological development

Phenological development was recorded using BBCH codes ([2], [3]) for each vine. The vines differ only slightly in their development between the experimental plots. However, the difference in the stage of development in round 7 is striking, from which it can be concluded that before the start of irrigation, trial plot B had an advantage over A in terms of plant development.



Representation of phenological development using the example of experimental vine A5.

Conclusion: Overall, the phenological development of the vines in the experimental fields is comparable. Diseases were not detected.

Development of biomass and quality
Grape length
The length of the grapes was measured as soon as they began to develop. From each vine, 9 bunches were randomly selected. Since the same bunches were not chosen each time, there are certain variations from one round to the next. The measurement was taken with a folding rule from the first branch of the grape to the lowest grape (see Annex A1). It is interesting to note the relative development between the experimental plots.

Average values of grape length measurements in cm.
(Red line represents begin of irrigation on 14 July 2022

		Runde 1	Runde 2	Runde 3	Runde 4	Runde 5	Runde 6	Runde 7	Runde 8	Runde 9	Runde 10	Runde 11	Runde 12
ID	Anzahl Reben	21.04.	03.05.	17.05.	01.06.	14.06.	01.07.	12.07.	28.07.	11.08.	24.08.	06.09.	15.09.
A1-A9	9	NA	NA	NA	NA	**9.5**	**10.0**	**10.5**	**10.1**	**10.8**	**11.2**	**11.1**	**11.3**
A10	1	NA	NA	NA	NA	**7.1**	**9.6**	**10.3**	**10.1**	**10.1**	**11.2**	**10.3**	**10.8**
B1-B10	10	NA	NA	NA	NA	**10.1**	**10.7**	**11.4**	**11.3**	**11.3**	**12.1**	**13.6**	**12.2**

Tab. 3: Auswertungen für die Messungen der Traubenlänge.
AM = Abschlussmessung, EM = Erstmessung, BB = Beginn Bewässerung.

ID	Anzahl Reben	Absolute mittlere Traubenlänge bei AM	Absolute mittlerer Traubenlängenzuwachs seit EM	Relative mittlerer Traubenlängenzuwachs ab EM bis BB	Relative mittlerer Traubenlängenzuwachs ab BB bis AM
A1-A9	9	**11.3**	**1.8%**	**1.0%**	**0.8%**
A10	1	**10.8**	**3.7%**	**3.2%**	**0.5%**
B1-B10	10	**12.2**	**2.1%**	**1.3%**	**0.8%**

The evaluation of the grape length shows that in absolute numbers the experimental plot B had better conditions from the beginning of the measurement (round 5), respectively on average the grapes were already somewhat larger (also at the time of the start of irrigation).

The comparison between the plots gives similar figures in terms of relative growth. After the start of irrigation, no difference between the plots is noticeable. The single trial vine in the non-irrigated area stands out for the strong difference between the growth before and after the start of irrigation.

Conclusion: Overall, the relative growth of the grapes between the two plots is comparable

Oechsle (sugar content)
From the beginning of grape discoloration, the °Oechsle degree of two grapes of a cluster per grapevine, one at the top and one at the bottom, were measured with a refractometer. The average of the two values per experimental plot is shown in Tab. 4.

Tab. 4: Durchschnittswerte der beiden (Beere oben und Beere unten). °Oechsle-Messungen pro Versuchsfläche.
Der rote Strich repräsentiert den Beginn der Bewässerung am 14. Juli 2022.

		Runde 1	Runde 2	Runde 3	Runde 4	Runde 5	Runde 6	Runde 7	Runde 8	Runde 9	Runde 10	Runde 11	Runde 12
ID	Anzahl Reben	21.04.	03.05.	17.05.	01.06.	14.06.	01.07.	12.07.	28.07.	11.08.	24.08.	06.09.	15.09.
A1-A9	9	NA	NA	NA	NA	NA	NA	NA	NA	NA	**65.3**	**81.5**	**89.2**
A10	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	**69.5**	**91.0**	**92.5**
B1-B10	10	NA	NA	NA	NA	NA	NA	NA	NA	NA	**66.6**	**82.0**	**93.4**

In contrast to the vines in plot A, Oechsle degrees > 100° were already measured for the grapes of vines B1 and B6.

In round 12 (15.09.20922), the total bunches per experimental vine were harvested and the °Oechsle and weight (g) were measured; cf. Fig. 4.

Abb. 4: °Oechsle-Messungen Messung bei den Versuchsreben (15.09.2022).

Tab. 6: Auswertung für die Messungen des °Oechsle-Grades bei der Ernte der Versuchsreben. VR = Versuchsrebstock, VF = Versuchsfläche.

	Mittelwert aller VR pro VF	**Einzelmessung (Gesamt-ernte aller VR pro VF)**	**Mittelwert pro VF (Gesamt-wert bei Haupternte)**
ID	Runde 12	Runde 12	Haupternte
	15.09.2022	15.09.2022	27.09.2022
A1-A9	**87.4**	***89.5***	**100**
A10	**88.0**		**99**
B1-B10	**92.8**	***90***	**100.8**

The results in Tables 5 & 6 show that experimental plot B has on average higher Oechsle values than trial plot A.

The mean values shown in Tab. 6 differ from the single measurement, although they were carried out at the same time. The measurement of two single grapes per vine obviously does not give a sufficiently representative indication, since the differences between the grapes or the vines are too great.

It is noteworthy that after combining all the grapes and measuring again the total harvest per trial plot, the differences between the Oechsle contents decreased significantly and were of a similar order of magnitude to the main harvest of September 27, 2022.

Conclusion: Overall, the Oechsle contents are comparable between the two experimental plots. However, they were marginally higher in field B.

Grape weight

Comparison of grape weight per grapevine (standard deviation)

	ID	Anzahl Trauben	Runde 12 15.09.	Gewicht pro Traube		ID	Anzahl Trauben	Runde 12 15.09.	Gewicht pro Traube
Unbehandelt	A1	9	586	65	Aqua4D	B1	14	1509	108
	A2	20	527	26		B2	16	1715	107
	A3	11	1586	144		B3	13	1339	103
	A4	11	1655	150		B4	15	2078	139
	A5	11	1272	116		B5	10	1038	104
	A6	11	1840	167		B6	10	1282	128
	A7	11	1595	145		B7	12	1575	131
	A8	4	307	77		B8	9	1095	122
	A9	14	1740	124		B9	9	1439	160
						B10	14	2499	179
		Max	*1840*	*167*			*Max*	*2499*	*179*
		Min	*307*	*26*			*Min*	*1038*	*103*
		Mittel	***1234***	***113***			***Mittel***	***1562***	***130***
		SDAW	*561*	*44*			*SDAW*	*425*	*24*
unbe-wässert	A10	13	1121	86					

The weighing of the grape harvest of the experimental vines shows a clear difference between the two experimental plots; cf. Tab. 7. It is striking that in Plot A three vines have a strongly below-average weight (A1, A2 and A8, yellow) while in Plot B two vines (B4 and B10, green) show above-average values. The higher standard deviation in the untreated field indicates that the variability of these vines is higher than in the AQUA4D field. Vine A8 had a very low cluster count (A8) and vine A20 had a very high cluster count, but with very low individual weight. Vines A1 and A2 are located in a zone that was already identified by AQUA4D as a "zone of reduced vigor" during the drone flight on July 7, 2022, i.e. before irrigation began.

Conclusion: Overall, a higher grape weight per trial vine could be achieved in Plot **B**. The higher harvest weight results, among other things, from the general vitality advantage of the vines at the beginning of the vegetation period. The total harvest of the trial plots on September 27, 2022, shows a similar picture with regard to weight, i.e. the trial vines were representative of their respective plots.

Discussion

The monitoring of individual vines per experimental plot and the documentation of the phenological development have proven to be an interesting supplement to the investigations of AQUA4D (cf. overall report of AQUA4D / FUAG / Salgesch Municipality, 2022). The additional results provide an overview of the basic conditions of the plots and the vines before the start of irrigation. From this, it can be seen that the starting conditions of the area irrigated with technically treated water were slightly better. Comparable conclusions could also be drawn based on the data from AQUA4D.

It could be shown that in the first season of the trial, the 20% lower amount of water on the field irrigated with AQUA4D® water had no negative effect on the phenological parameters of the vines. The values for growth, Oechsle and harvest weight remained constant and even tended to be higher than in the reference field. The single experimental vine (A10) in the non-irrigated area does not provide sufficient information to make a statement about the non-irrigated area.

5.3.7 Harvest results

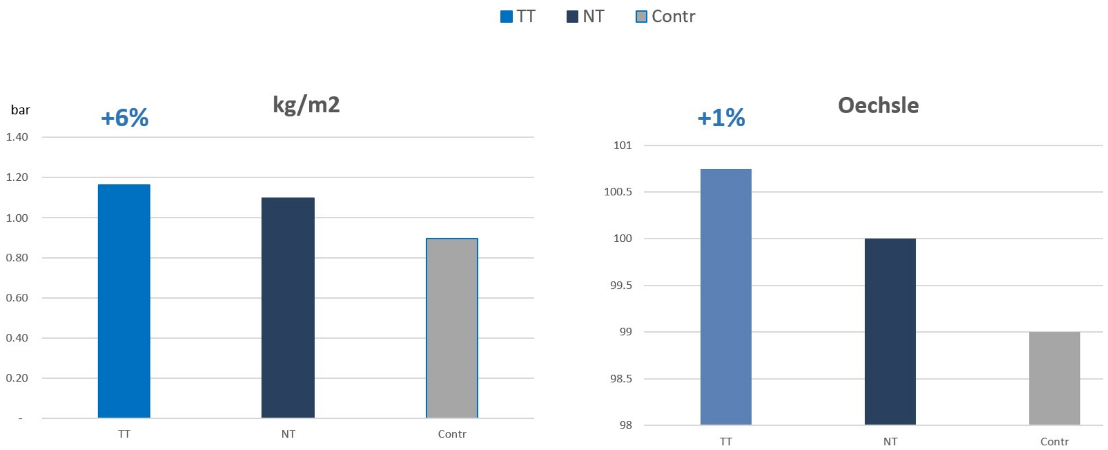
On 27/09/22, the NT, TT and CT fields were harvested on the same morning. The harvest was carried out by the same team of the Salgesch commune on both sides in the sectors; these sectors were defined by FUAG.

The grapes harvested on each plot (NT, TT and CT) were weighed separately. For the NT and TT plots, the sugar content (the degree Oechsle) was measured on four vines, and for the CT plot, on a single vine. These measurements were carried out by the municipality of Salgesch.

Testparzellen Aqua4D Salgesch

Erntedatum	Parzelle	Fläche	Sorte	Behälternr.	Oechsle	Gewicht abg.	Gewicht/m2
27.09.2022	NT		Pinot Noir	17	102	370	
27.09.2022	NT		Pinot Noir	15	100	366	
27.09.2022	NT		Pinot Noir	6	99	394	
27.09.2022	NT		Pinot Noir	14K	99	143	
		1160				**1272**	**1.10**
27.09.2022	nicht bewäss.	160	Pinot Noir		99	143	**0.89**
27.09.2022	TT		Pinot Noir	1	100	380	
27.09.2022	TT		Pinot Noir	3	103	379	
27.09.2022	TT		Pinot Noir	5	100	388	
28.09.2022	TT		Pinot Noir	20K	100	204	
		1160				**1351**	**1.16**

Salgesch, den 27.09.2022/HAG



The results show a 6% higher yield in weight and 1% higher degrees of Oechsle on the TT side compared to the NT side.

6 General conclusions

The aim of the project was to evaluate the irrigation water savings potential of AQUA4D® water treatment technology in irrigating vineyards in Valais, Switzerland.

The project participants agree that the following can be confirmed by the end of 2022:

AQUA4D® treatment saved 20% water compared to a vineyard irrigated with a drip irrigation system, and even more for plants under moderate water stress. The results confirm that the quantity and quality of the harvest is at least the same.

A main objective of the IrriSalgesch project was to prove that the concept of drip irrigation + AQUA4D® + monitoring/automation of irrigation would save water for irrigation on the entire vineyard area of the Lienne-Raspille project, a total of 1,000 ha.

Research and field analysis have already confirmed that replacing sprinkler systems with drip irrigation systems can yield savings on the order of 25%. To achieve this goal, it is necessary to monitor the situation in real time and optimize irrigation cycles based on this monitoring, with automated and remotely programmable irrigation.

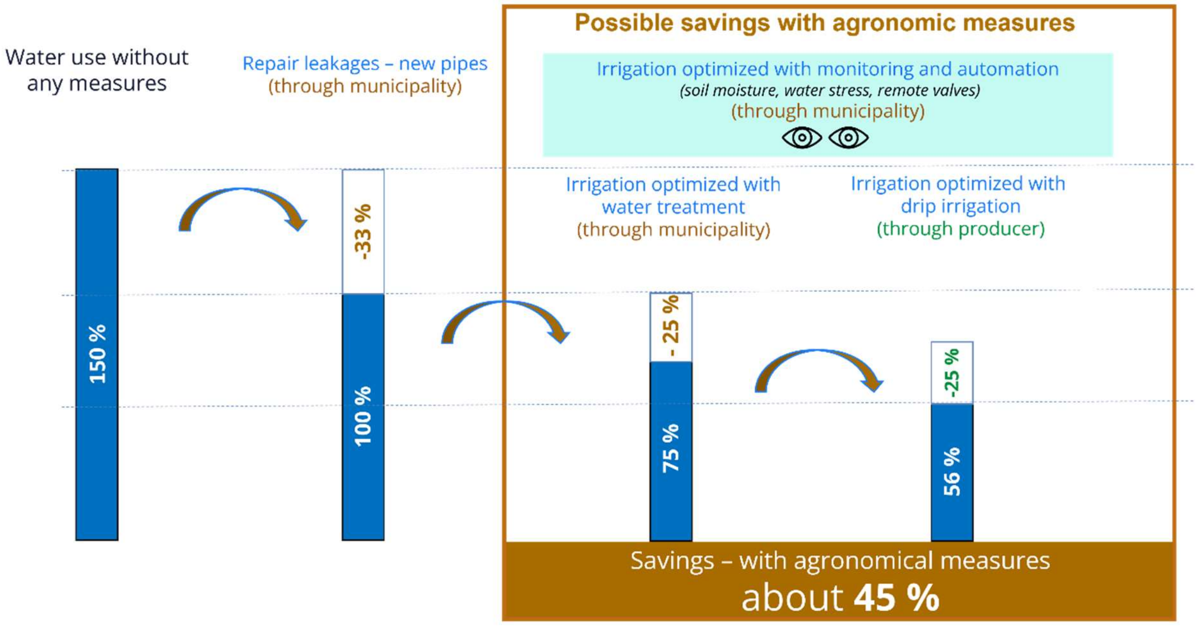
With additional savings of 20-30% with AQUA4D, water savings of about 45% can be achieved, with at least the same quantity and quality of crops. Based on their experience, the specialists at AQUA4D believe that the savings will be higher in the second year of irrigation than in the first year, as the plants adapt by developing hairy rootlets.

Because the vineyards in Valais are parceled over small areas, soil moisture monitoring and AQUA4D treatment can be efficiently and economically implemented across the entire irrigation network of a municipality or collective (in the context of irrigated and parceled agricultural land with growers working on widely separated land).

The conversion from spray to drip systems will naturally occur at the grower level as they replace their old systems.

For cost efficiency, we also suggest integrating sand filtration systems at a central level. It is important to filter the water that flows into drip systems well, as drip systems are much more prone to clogging than sprinkler systems. The coarse filters currently installed at the parcel level are not sufficient for this concept and, unless it has upstream central filtration, run the risk of clogging frequently. Taken together, this would all facilitate automated and optimized irrigation.

Order of magnitude of potential water savings, using cascade of measures:



Note on this graph

This project analyzes the possible savings with agronomic measures and aims to make water savings of at least 40% with these measures. Because the measure "Repair leakages – new pipes" is not an agronomic measure, it is set at 150%, by decreasing 33% of this 150% we arrive at 100%.

With the centralized measure of treating the water with AQUA4D, we reduce this 100% to 75%. By integrating drip irrigation, we reduce this 75% by another 25% (25% of 75% = 19%). The agronomic measures create water savings of 25% plus 19% = 44% (about 45%).

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8 Annexes

8.1 Annex 1 - FUAG Report - Field trial vine development with AQUA4D IrriSalgesch Project, stand report trial monitoring (focus phenology), Visp, November 2022 (separate document in German).

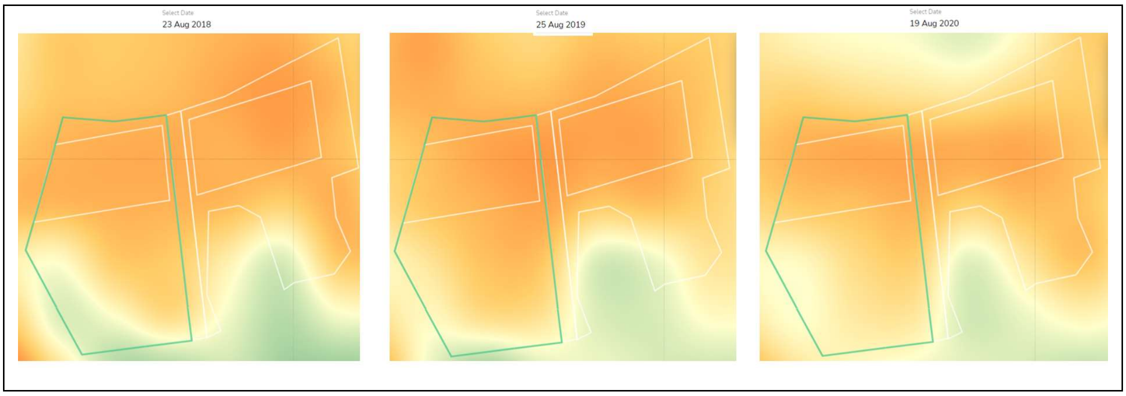
8.2 Annex 2 - Water consumption for vineyard irrigation

Category	DM101 - Wasserfassung Klosterli	DM103 - Ausgang Klosterli Richtung Brinju	DM201 - Ausgang Brinju Reservoir Richtung Ost	DM202 - Ausgang Brinju Reservoir Richtung West	DM251 - Kammer Varen
	m3	m3	m3	m3	m3
1.2022	48'505	0	33	33	0
2.2022	709	0	9	9	0
3.2022	3'589	0	0	0	0
4.2022	226'361	248'521	11'357	17'554	0
5.2022	302'852	321'903	25'299	35'108	0
6.2022	323'394	419'356	66'629	79'537	295
7.2022	133'240	124'642	30'166	23'530	9'218
8.2022	139'726	21'602	3'091	3'636	17'885
9.2022	42'814	13'208	4'493	6'531	22'686
10.2022	242'013	96'297	10'974	16'092	59
11.2022	242'973	0	1	1	0
12.2022	0	0	0	0	0
	1'706'176	1'245'529	152'052	182'031	50'143
					m3
			Wasserverbrauch	**2022**	**384'226**

Salgesch, den 22.11.2022/HAG

8.3 Annex 3 - Aerobotics - Selection of experimental fields

The Aerobotics platform provides historical satellite imagery showing soil moisture and plant vigor with NDVI (health, chlorophyll) measurements and soil level moisture. Analysis of these images revealed that the lower (southern) portions of both fields NT and TT had significantly different conditions for vegetative development than the upper (northern) portions. The lower portion of field NT is very wet most of the time; operators said that there is an underground watercourse at this location. In 2021, a year with a lot of rain, this part of the vineyard had plants that were choking at the roots. In the upper part, on the other hand, from the satellite images, it was possible to identify two "subplots" on the NT and TT plots, labeled "identical sunlight" (see "experimental plots" in 4.2), with identical behavior and identical sunlight).

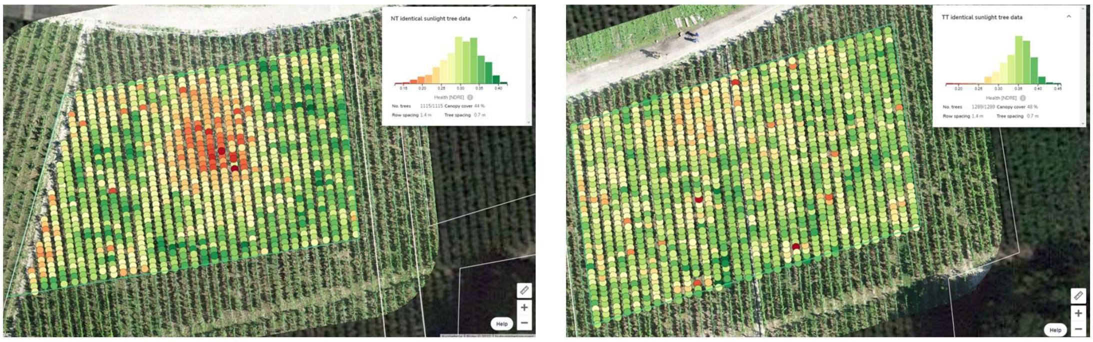


Analysis of the data collected during the first drone flight

The first drone flight took place on 07/07/22, before the first irrigation. After this flight, the processed and analyzed data were available on the Aerobotics platform, which allowed to detail the initial condition of the vines.

It was confirmed that the lower (southern) parts of the two plots NT and TT were not comparable. Thanks to the accurate data, it was recognized that in the vineyard group "NT identical sunlight", a circular group of vines had a worse health condition and vigor compared to the surrounding vines (below, a red circle of vines, indicating a low NDRE). This was not visible on the satellite imagery. The FUAG project on phenological analysis of grapevines had selected 10 vines from both the NT and TT fields. These vines were selected before the vegetative phase, and their selection also included some vines in the smaller, weaker field.

The numerical analysis also clearly shows this difference due to this field.



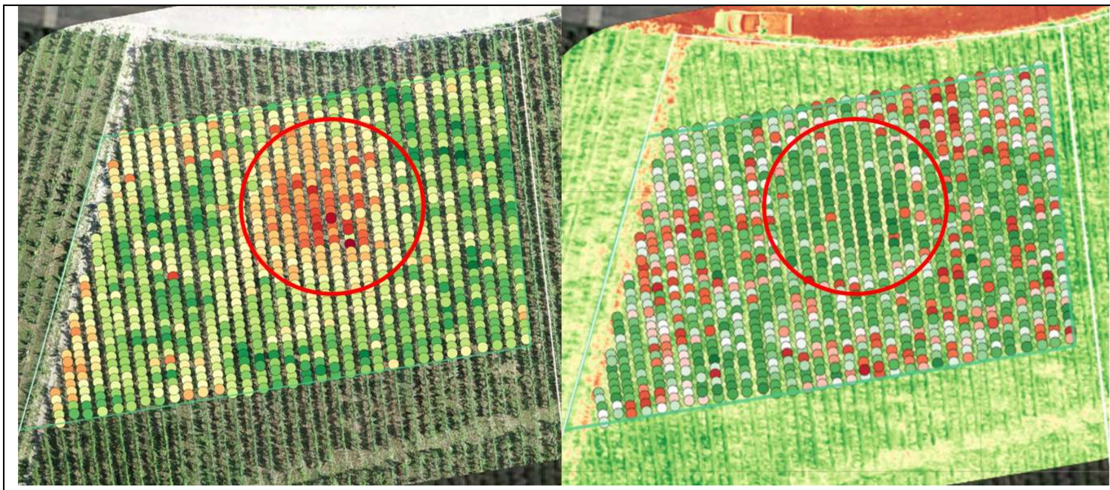
orchard_name	flight_date	tree_health	tree_vigor	tree_area_sqm	tree_width_m	tree_volume_cb
NT identical sunlight	07.07.2022	0.30	0.68	0.46	0.76	0.20
TT identical sunlight	07.07.2022	0.35	0.76	0.46	0.76	0.29
TT compared to NT		*14.8%*	*12.1%*	*0.2%*	*0.1%*	*43.7%*

To obtain even more similar groups of vines, the groups "NT center above", "TT center above" were chosen. The numerical analysis shows that the TT values for these groups were slightly lower than the NT values, but both very similar in health and volume.

orchard_name	flight_date	tree_group	tree_health	tree_vigor	tree_area_sqm	tree_width_m	tree_volume_cb
Vineyard NT	07.07.2022	NT center above	0.36	0.73	0.46	0.76	0.20
Vineyard TT A4D	07.07.2022	TT Center Above	0.34	0.72	0.45	0.76	0.20
		TT compared to NT	*-4.2%*	*-1.9%*	*-0.6%*	*-0.3%*	*1.8%*

Evolution of the "identical sunlight NT" group due to the situation established after the first flight.

The comparison between the two "identical sunlight" groups NT and TT, selected before the first drone flight, was influenced by this group of vines on the NT side, whose health status was worse at the beginning of the experiment. The second drone flight showed that these vines caught up in terms of health and volume, compared to the other vines.



Links: NDRE-Situation am 07.07.22. Rechts: die Entwicklung des NDRE bis zum 29.08.22.

Plants in the red circle that were in poor health caught up compared to the others.