USER-PA

USability of **E**nvironmentally sound and **R**eliable techniques in **P**recision **A**griculture

Project number 14308

Final Report – ICT-AGRI era-net

1. Project Data

Title: USER-PA USability of Environmentally sound and Reliable techniques in Precision Agriculture.

Description: USER-PA concept planed as a framework and concrete applications for the farmer that will demonstrates reliable Precision Agriculture solution, focusing in an operational system for irrigation in orchards and vineyards. USER-PA dealt with integration of canopy and fruit sensors with autonomous mobile vehicles and wireless sensor networks for providing spatial data for high value crops (vineyards and apple orchards) on irrigation and harvest management.

Funding: ICT-AGRI, EU and local national authorities.

Partners: *ADU, Turkey* - Ismail Bogrekci and Pinar Demircioglu; *ARO, Israel* – Victor Alchanatis, Ronit Rud and Asaf Alon; *ATB, Germany* – Manuela Zude, Jana Käthner and Christian Regen; *CERTH/IRETETH, Greece* – Spyros Fountas and Zisis Tsiropoulos; *FBH, Germany* – Bernd Sumpf and Martin Maiwald; *HAU, UK* – Simon Blackmore, Leo Biggs and Sam Wane; *HES-SO, Switzerland* – Dominique Fleury, Jeanne Giesser, Reynald Pasche and Yves Blondel; *PoliMi, Italy* – Alessandro Torricelli; *UCPH, Denmark* – Soren Marcus Pedersen and Tseganesh Wubale.

Date: 2013 – 2016, with accordance to each country budget scheduling.

2. Introduction

A number of technologies originating from ICT, has been successfully applied in agriculture. Nevertheless, sensor solutions have not been adopted into common agricultural practice. Two main gaps were identified, that this project was approaching to abridge: 1. Reliability - systems with insufficient reliability for everyday use in harsh conditions, and limited robustness of calibrations. 2. Usability - techniques were applied as isolated approaches without synergy of sensors' data. In combination with the limited insight of the farmers with ICT, it limited their adoption. According to literature reviewed, there are a lot of advancements in each one of the individual fields of precision agriculture, but there is a lack of integrated systems. This project was focused in integration of existing components of sensing, platform and information management, to one entity, to overcome the obstacle of segmented operational chains. USER-PA proposed a conceptual framework and concrete applications for the farmer.

The main goal of the USER-PA project was to develop and demonstrate an integrated and reliable Precision Agriculture solution for orchards and vineyards considering spatial information on irrigation and harvest management. The objectives were: (1) to establish and develop technologies to sense, acquire, analyze and present to the farmer information that will enable him to manage the crop more efficiently and with reduced environmental footprint; (2) valuate the economic advantages of USER-PA for the farmers, and its environmental impact for greener agriculture; and (3) demonstrate the capabilities of USER-PA to farmers, extension service and other stakeholders.

The research activities that were included in the project were: (1) development and assimilation of selected sensors; (2) development of an autonomous platform to carry/communicate with the sensors and gather the information from the field; (3) transform acquired raw data into useful information that the farmer can assimilate; and (4) assessment of cost efficiency and demonstration to relevant stakeholders. These were formulated as a work plan comprised of 3 main components: technical issues (WP1-WP3), agricultural management resources (WP4 and WP5), and field trials including demonstration (WP6 and WP7) (Figure 1).

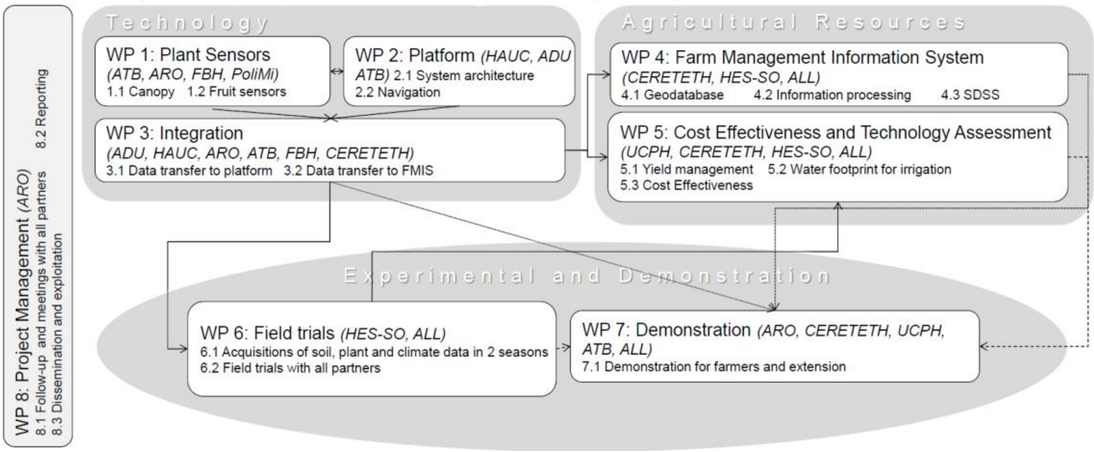


Figure 1. Perth diagram showing connection among work packages (WPs) and related participants.

Detailed activities relating specific deliverables for each WP can be found in section 4, "Performance evaluation".

3. Project major results

The project resulted with several major outcomes that can be implement immediately in practice or/and may be used in future applied research:

Agronomy	- Decrease of irrigation increased pheophytin in apple. - Decrease of irrigation by 50% obtained the same yield with higher sugar content. - Decrease of irrigation with the same yield, achieved as a result of collaboration with other teams and their sensors.
Technology	- Conversion of a current, commercially available vehicle for the purpose of autonomous mobile platform, while preserving its original designs intact for common agricultural missions. - Development of safety system for autonomous tractor. - Novel optical fruit sensors were tested for the first time in the orchards. - Android application was developed for non-automatic data collection as complementary tool supporting farm management information system.
Methodology	- Formalization of concept for calibration of fruit sensors. - Reliable calibration of canopy and fruit sensors, needs longer period than what was given within the project framework (i.e. more than 2 years of field trials at the same location). - Professional standard of safety systems for the autonomous tractor were developed. - Exchange of specific measuring protocols due to intensive cooperation of interdisciplinary teams during fields trials. - Demonstration on larger scale should be scheduled as satellite of other farmer / agricultural event.

Budgeting	- The framework of no central finance control resulted in differences of timetable, i.e. deliverables performance versus the planning. - Some activities required to achieve assigned deliverables were overspent, e.g. mobile platform transportation to field trials sites, tractor conversion and sensors' integration.

4. Performance evaluation

WP1 – Plant sensors

Canopy sensors – ARO, Israel (deliverables D1.1s) were developed and canopy status was evaluated. Thermal infra-red camera (FLIR system, A655sc 8-13 μm) was used for evaluation of water status based on canopy temperature and meteorological data. A Canon sx110is in the VIS range was used for evaluation of canopy coverage (vigor) based on reflected energy in 3 bands (*Red, Green and Blue*). Imaging was done simultaneously with the two cameras. First year local experiments were focusing in formation of imaging protocol (angles and distances); and adaptation of existing model associates biophysical measures and sensed data. Figure 2 describes the imaging system used in the project field trials and some results. Additional details can be found in appendix A.

Fruit sensors – ATB (Germany), PoliMi (Italy) and FBH (Germany) (deliverables D1.2s) were developed and their status were evaluated. It included 3 different measuring units (Figure 3). Earlier studies suggested that selective harvest may be done based on time series of fruit NDVI values (Figure 4a). Following this outcome, a multi-spectral multi-distance sensor (optical Spider) in the VIS-NIR spectral range was developed. It was attached to fruits during the growth season and recorded in-situ measures of light absorption or scattering, used later for calculation of NDVI (see more details in appendix B). The portable unit of time-resolved spectroscopy (TRS) was used to nondestructively retrieve information on the internal optical properties of fruit, namely absorption and scattering coefficients (see details in appendix C). Both units, the Spider and the TRS, were used to evaluate the chlorophyll content of the fruit based on two wavelengths in the red and NIR range (680 nm and 780 nm respectively). The last unit, the portable Raman, was used to characterize additional chemical properties of fruit skin. Figure 4 describe selective results obtained with fruit sensors.

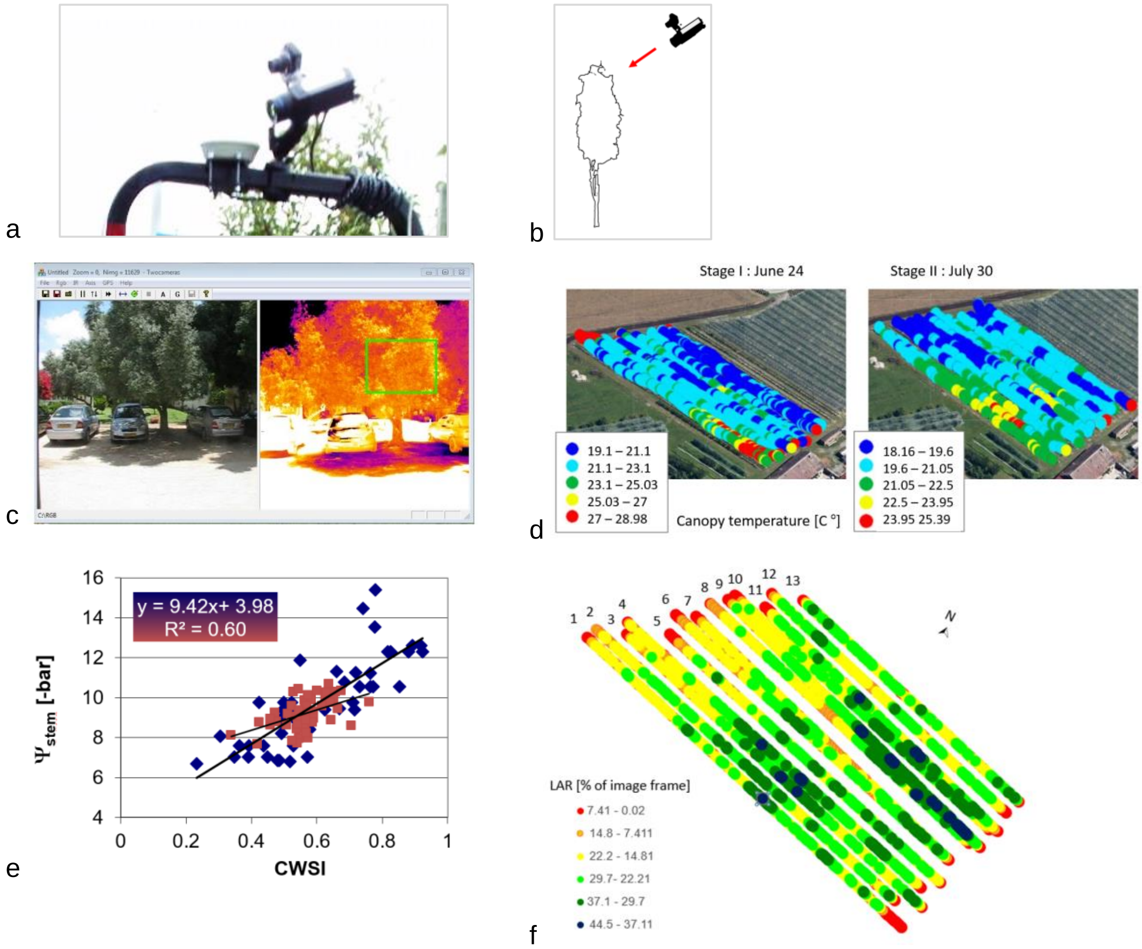


Figure 2. Imaging system, the *canopy sensors***:** cameras mounted on a bar of the mobile platform (**a**); imaging set-up (**b**); tow cameras interface for the system operator, the RGB and TIR on-line displays (**c**); canopy temperature (Tc) 2015 field trials Switzerland before and after correction of irrigation. Used for estimation of water status based on calculation of crop water stress index (CWSI) (**d**); correlation of stem water potential and CWSI in vineyards, using existing model (in *blue*, 2005, Muler et al., 2005) and embedded project data (in *red*, 2013, field trials, Israel) (**e**); and percentage of canopy coverage, June 24, 2014 field trials Switzerland (**f**).

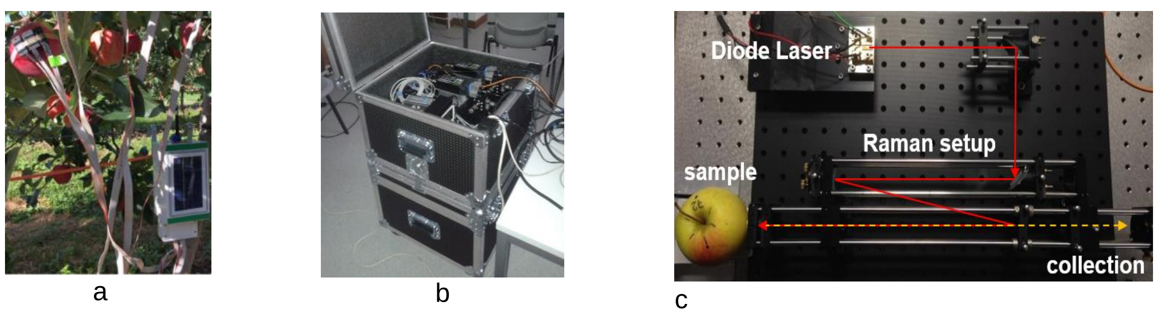
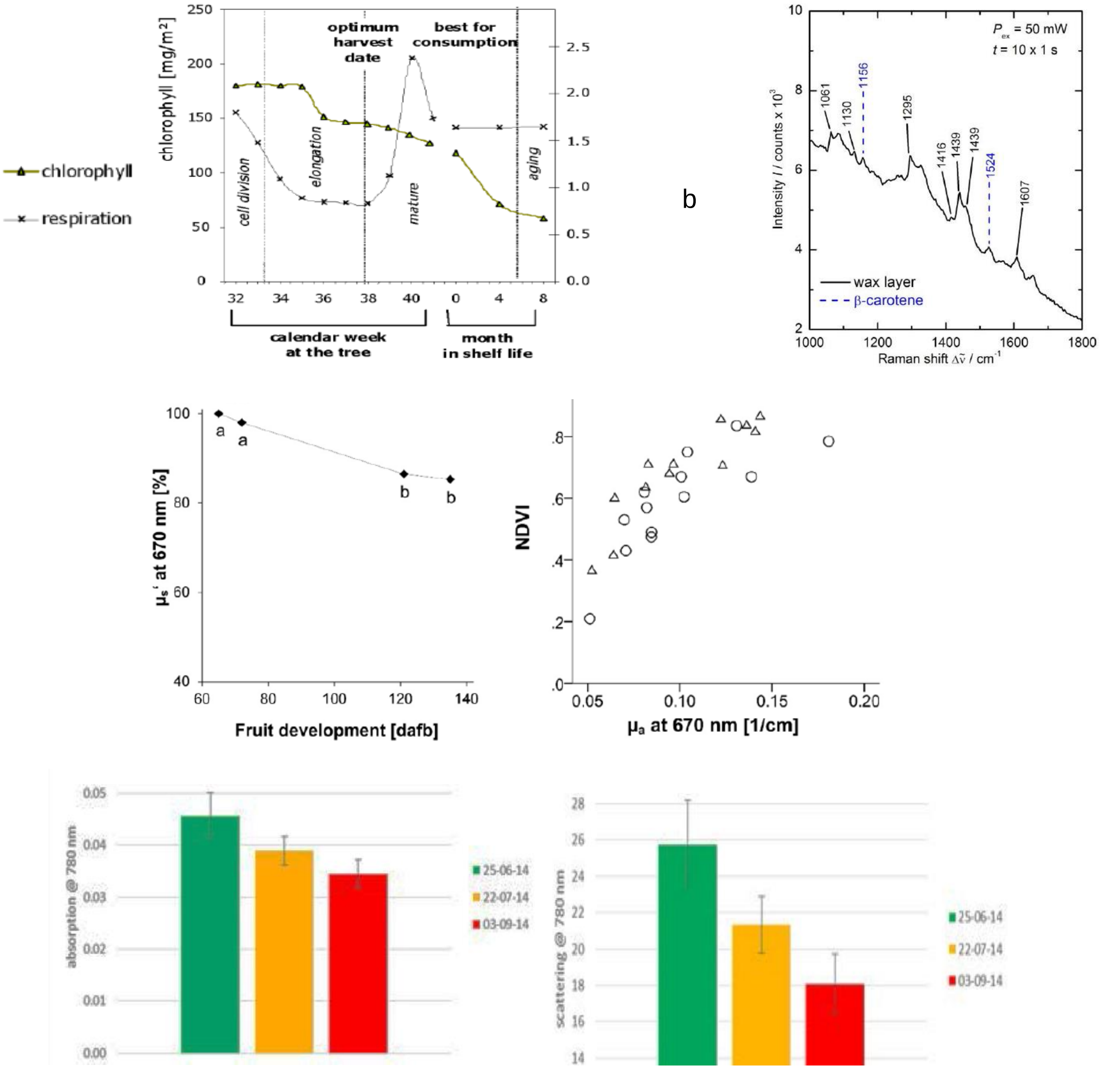


Figure 3. *Fruit sensors:* optical Spider (**a**); portable TRS unit (**b**); and portable Raman design (**c**).



e

	Chl_a [mg/m2]	Chl_b [mg/m2]	Pheophytin [mg/m2]	NDVI [0; 1]
30.06.2014	37	19	24	0.93
27.07.2014	22	11	13	0.79
05.09.2014	7	5	9	0.64

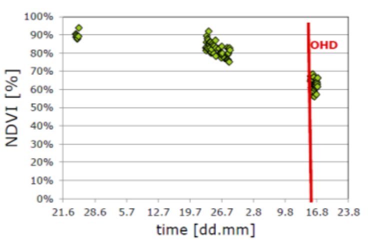


Figure 4. Data and information obtained with *fruit sensors*: earlier study of optimal harvest time (Zude-Sasse et al. 2002) (**a**); Average of ten Raman spectra of an apple with $\lambda_{ex\text{-}1}$ = 784 nm and ρ_{ex} = 50 mW (**b**); absorption coefficients along growth period (**c** left) and correlation with NDVI values (Seifert et al. 2014) (**c** right) for two late harvest dates (triangles and circles); absorption and reduced scattering (Torricelli at al. 2015) (**d**); NDVI, chlorophyll, Pheophytin values (in the table) and optimal harvest day (OHD), 2014 field trials data (**e**).

All fruit sensors' data acquired parallel to chemical-physical measures of fruit pigments, size and quality, and used as references (see selective data in appendix B).

WP2 – Platform

There were planned two platforms (Figure 5) each to be tested in different site:

a. *The HAU, UK* platform developed using an existing preferable commercial vehicle.

b. *The ADU, Turkey* platform developed as a whole within this project framework.

a b

Figure 5. The designated platform: a converted current, commercially available vehicle for the purpose of the (**a**) and an original designed platform (**b**). An example for the test while design of platform b, can be found in appendix D.

System architecture (deliverables D2.1s) were design incorporating both functional and safety aspects. A prototype, a converted tractor, and the system electronic were tested. Detailed architecture, vehicle, safety specification, report of prototype test and long term support of the UK platform can be found in appendices E and F.

Navigation system (deliverables D2.2s) for the autonomous mobile platform was developed. The navigation sensors were integrated into a perception head of the autonomous platforms, and were designed to implement both deterministic tasks and reactive behaviors in vineyard and orchard environments. It included RTK, GPS inertial measurements units, laser range finder, LVDT and network Wi-Fi receiver and antenna.

Navigation tested with SAFAR software package. Laser rangefinder algorithm was anticipated to be complete shortly after closing meeting. For details see appendix G.

WP3 – Integration, teams of platform, plant sensors and farm management information system, *HAU – UK, ADU – Turkey, ARO – Israel, ATB – Germany and CERTH/IRETETH - Greece*

Interfaces and integration of sensors to mobile platform (deliverables D3.1s) were partly tested. Definitions of fully integrated autonomous system during 2015 field trials, using canopy sensors, was not possible due to lack of funding for the transport of the adopted tractor, UK mobile platform. The transport of the converted tractor in 2014 filed trials to Switzerland, enabled completion of early stage test with no opportunity to examine needed changes resulted from the first year field campaigns. These tests conducted in the experimental apple orchard did not included all plant sensors. Detailed diary of events from 2014 filed trial testing the converted tractor is presented in appendix H. Additional tests of the mobile platform were conducted in 2015 in HAU, UK. No test was conducted in Turkey in project experimental plots.

Consequently, automated data acquisition using the autonomous platform in the orchard/vineyard was not ready for full demonstration. Automated data acquisition generated by canopy sensor, in project field trials, was done using alternative non-autonomous platform. Positional data (GPS) were provided independently (NMEA protocol), and further information based on the canopy sensors was developed as part of the work on the farm management information system (FMIS). Data of plant sensors, fixed and from the mobile unit were imported into FMIS, using nomenclature, format and metadata (deliverable D3.2) that were defined by all partners.

WP4 – Farm management information system

Development of *USER-PA Geodatabase*, *CERTH/IRETETH – Greece* and all (deliverable D4.1) was completed. Figure 6 displays USER-PA database architecture. For details see appendix I.

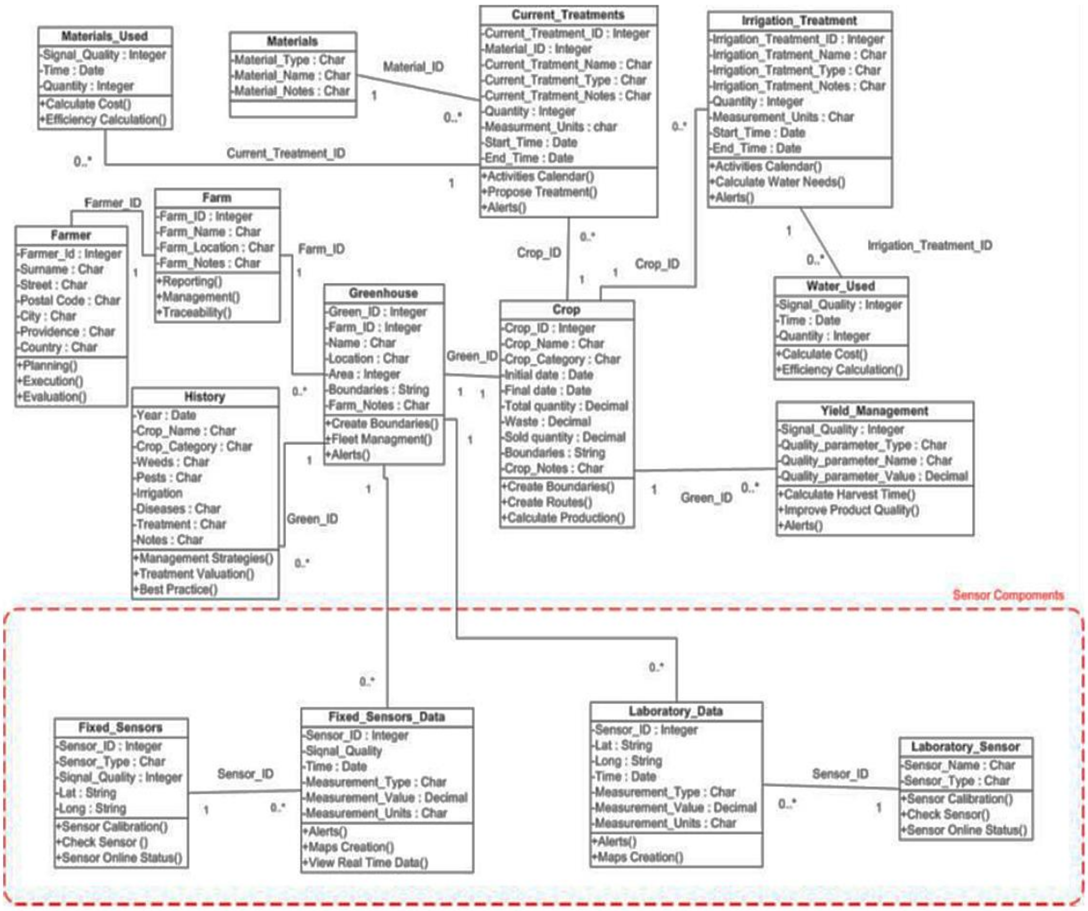


Figure 6. USER-PA database.

Web and android applications were developed and tested by offline information provided using automated canopy sensed data, navigation data, and manual fruit data recorded as a part of common filed work (Figure 7). Imported information provided by the sensors of plant (canopy and fruit), was visualized. On line data of navigation system was simulated (deliverables D4.2s). The rational for these deliverables detailed in appendix I (section of deliverable D4.2.2). The comprehensive description of FMIS web applications are in appendix J.

a b

Figure 7. Web application of USER-PA FMIS: Visualization of the experimental plot in Switzerland, the apple orchard (**a**), and an example of menu of sub actions displaying different form of data that can be uploaded (**b**).

Design and development of a decision support system (deliverables D4.3s) was partly achieved. This project was focused in technology and was not designed to investigate threshold values for triggering an action of irrigation or selective harvest. Reliable calibration of the canopy and fruit sensors considering the experiment plot, the apple orchard, needed longer period than what was given within the project framework. Decision rules relating irrigation were supplied for vineyard based on an existing model developed for semiarid-zone. Decision rules for irrigation in apple orchard in Switzerland based on plant/fruit do not exist, nor vital information of a protocol monitoring irrigation based on plant measures such as stem water potential. Decision rules for selective harvest of apples were formulized based on two years seasons and could be only tested comparing to farmer decisions and historical information. For details see appendix K.

A feedback relating the FMIS applications were given during filed trials while development of systems user's interfaces and experiencing usages of web and android applications. Report on users satisfactory can be found in appendix K (section of deliverable D4.3.2). It included project partners and farmers from Greece. The extent of farmers' favoring the future usage of FMIS were depending on their economic status, their farm size and their familiarity with new technologies.

WP5 – Cost effectiveness and technology assessment

Cost of different USER-PA scenarios were assessed based on one field site in Switzerland with more emphasis on both water savings and benefits from better fruit quality at harvest.

Yield management, *UCPH – Denmark, HES-SO – Switzerland and CERTH/IRETETH – Greece*, (deliverable D5.1), list the relevant measurements that were collected from the field trials during the growing season, used for the economic assessment in WP5 and for the decision support system in WP4. It included data of yields and quality parameters, as well as input applications. It outlines a description of the external data needed for the decision support including, market prices, input prices and expected precipitation for the local region.

Water and fertilizer footprint for irrigation (deliverable D5.2), *UCPH – Denmark, CERTH/IRETETH – Greece and HES-SO – Switzerland*, was done based on data from the apple orchard in Switzerland. Three scenarios were examined considering level and variability of precipitation, weather and within field characteristics:

- BASE scenario: where precipitation amount is an average, weather variability is moderate and variabilities in a field are somehow considerable.
- LOW scenario is characterized by plenty of rainfall, low variability in weather and field attributes.
- HIGH scenario: high variabilities both in weather conditions and field characteristics added to generally low precipitation. In the situation where the demand for precision management is very high, correspondingly high potential for water saving from the use of the USER-PA system is expected. In this case, demand for precision management is high requiring high investment cost and promising high benefit.

Comparison of water application with and without decision support system (DSS) was done for these scenarios. Water footprint of the apple orchard was achieved based on data collected for testing the FMIS and compared to nowadays conventional irrigation (farmer decision). Fertilizer footprint was not examined since the experimental design set-up included only controlled drip irrigation. For details see appendix L.

Cost-effectiveness UCPH – Denmark (deliverable D5.3) was found to be very sensitive to marginal changes in fruit price and capital cost. Under the assumptions maintained, it is found that adoption of USERPA under the LOW scenario is not economically justified as compared to farmer practice. Under the HIGH scenario, the proposed USERPA technology generates positive net benefit over that of existing best practice. Complete report in appendix L (section of deliverable D522).

WP6 – Field trials

Field trials design and set-up, *HES-SO, Switzerland and ADU –Turkey* (deliverable 6.1) were completed. There were allocated experiments' site with suitable infrastructure of irrigation system, electricity and storage. Table 1 depicts the two experimental sites and Figure 8 shows the experiment set-up.

Table 1. Experimental sites of field trials

Property of	**Switzerland**	**Turkey**
Site location	Prangins (VD) ~ 46°23' N, 6°14' E	Aydın ~ 37° 46' N, 27° 45' E
Altitude	380 m	N.D.*
Soil	Clay 26%, Silt 29%, Sand 45%	Sandy loam: pH 8, CaCO3 3.9%, organic matter 1.34 %, CEC 12.76[me/100g], total salt 0.022%
Precipitation	750 mm	N.D.
Specie	*Malus x domestica* (**apples**)	*Vitis vinifera* (**grapes**)
Variety	Gala Brookfield	Osmanca, Gelin (table grapes)
Rootstock	Pajam 1	Fercal, 1103 Pa, 140 Ru, 110 R, 41 B (American)
Harvesting	September	September – early October
Irrigation	Mainly precipitation, additional irrigation by drip irrigation when needed	Drip irrigation
Distance between rows	2.5 m (effective distance – canopy to canopy)	2.5 m (effective distance – canopy to canopy)
Trees' age & height	5 years old, 3.5 m	1 and 4 years old, N.D. m
Actual present view		

* N.D. stand for 'no data' supplied

The experimental activities were not planned to produce data on the effect of different treatments on the expected marketable value of the fruits. The experiments were focused in scheduling of harvesting date and irrigation. Tests of the proposed system, acquisition of field data using a mobile platform and FMIS, were planned to be conducted in apple orchard – Switzerland, and vineyard – Turkey. In order to enable substantial test of FMIS focusing in an operational system for irrigation, there were applied three levels of irrigation (0, 50 and 100% of the conventional amount).

The coming sections of deliverables 6s' depict selective items from field trials conducted in Switzerland in the apple orchard. There were no field trials in Turkey in vineyard.

Soil analysis of the orchard site in Prangins (VD), 1243 trees over an area of 45 m × 117, showed some difference in composition and texture comparing north and south side of the orchard. Topography characterized with slight slope (~ 1.14°, estimation) from the center of trees rows tops, towards the edges of the rows, the lower parts. This results is in line with results of hot spot analysis based on EC measurements done at the apple orchard prior to field campaigns involving the canopy-fruit sensors (figure 8).

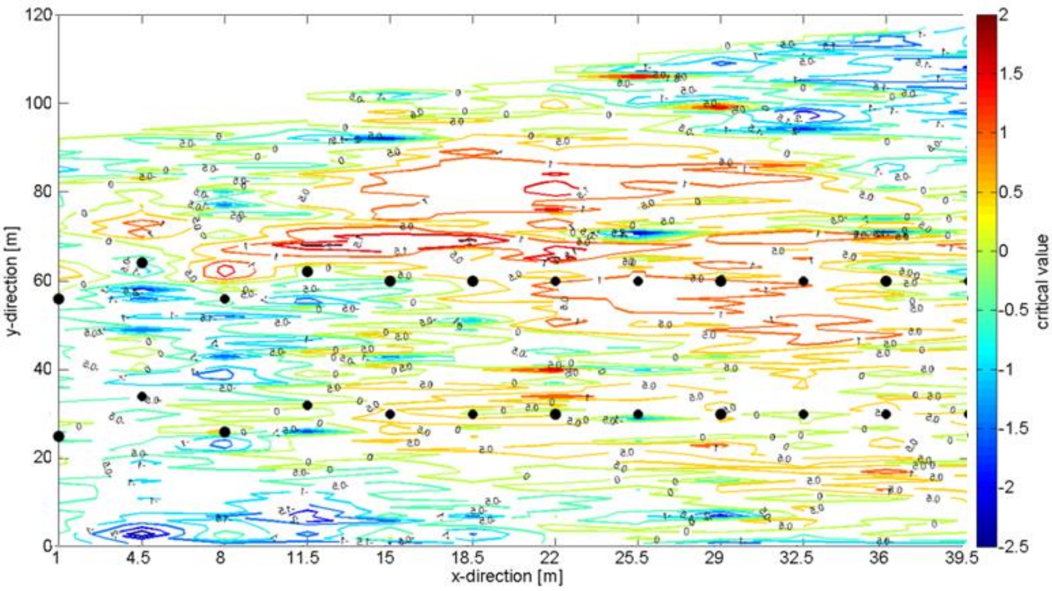


Figure 8. Isolines of critical values obtained from hotspot analysis of ECa measurements carried out on the data of Changins orchard. The osmotic potential is plotted with circles presented as small up to 942 mmol/kg, medium up to 1115 mmol/kg, and large up to 1289 mmol/kg.

The orchard was divided into sections of 'sensor based response', 'no response' and a control part - the 'farmer' section. It was planned to test the proposed system and FMIS by comparing practice results using sensors, FMIS and conventional farm management. In 'sensor based response', decisions relating irrigation and optimal harvest day (OHD) were planned to be taken upon FMIS information whereas 'no response' section was left with no response. 'Sensor based response' was used also for estimation of OHD since the optical Spider was positioned there (tree number 201, in the subsection were the plastic remained till the end of the season). In 'farmer' section, all practices and decisions were done as in previous years – no system sensor and FMIS information was considered. Figure 9 display experiment setup for the apple orchard in Switzerland,

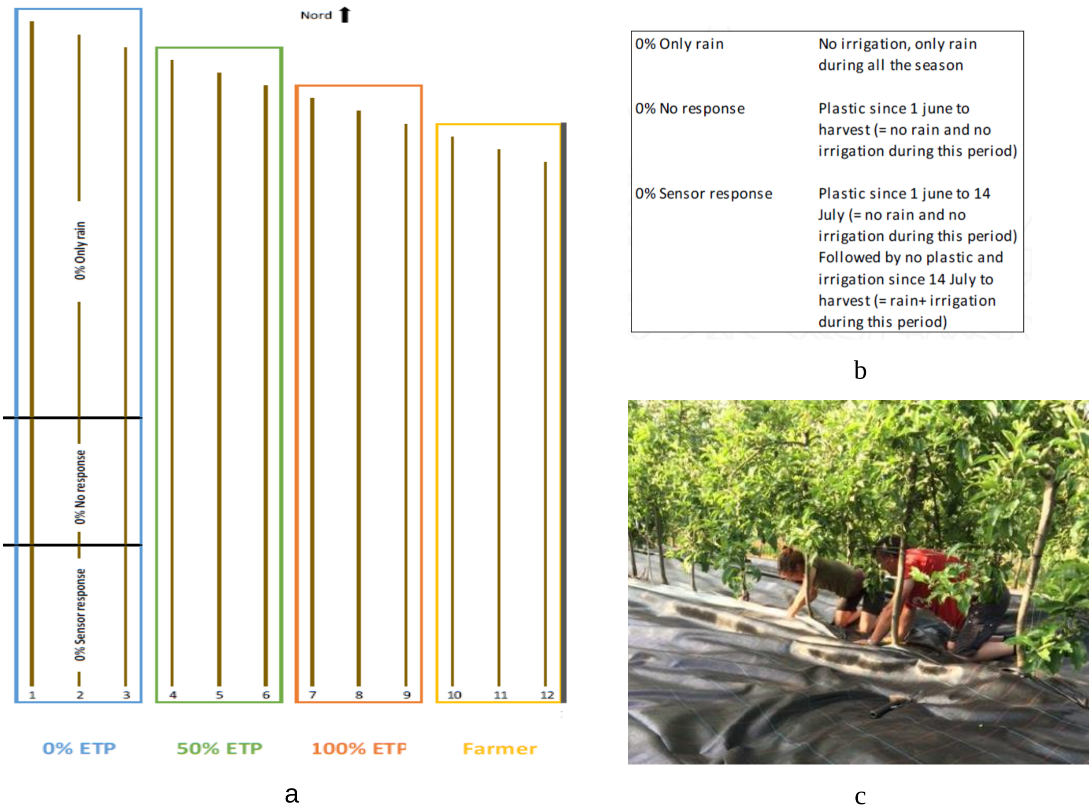


Figure 9. Experiment site field trials Switzerland: treatment setup (**a**), explanations for subdivision of '0% ETP' rows (**b**), and plastic soil cover at sub row '0% ETP' to minimize direct effects of precipitation – the 0% no response (**c**).

Data acquisition was done during two seasons *in the experimental site of HES-SO – Switzerland, teams of canopy-fruit sensors – ARO, ATB, PoliMi, FBH – and FMIS -*

CERTH/IRETETH and UCPH (deliverable 6.2). The measurements were conducted during the summer and included three field campaigns in each year: canopy sensing, canopy and fruit sensing, and yield measurements (June to September). During these campaigns meteorological data were supplied using the service of *Agroscope*, *Institut des sciences en production végétale IPV* (http://www.agroscope.admin.ch/org/00262/07415/index.html?lang=fr). Table 2 summarizes field measurements.

Table 2. Measurements in field trial campaigns, Switzerland

Sensor	Contact	Reference readings	Ref. contact
Irrigation scheduling			
Thermal camera	ARO	VPD, T, rH, wind speed, radiation	HES-SO
		Stem water potential, soil ECa, dendrometer	ATB
Laser scanner *	HAU	LAI *	HES-SO
NDVI camera **	ARO	LAI	HES-SO
Raman	FBH	Cuticle main compound	ATB
Harvest Management			
Spider	ATB	Chlorophyll a, b, pheophytin, ethylene	ATB
TRS	PoliMi	(Chlorophylls), fruit flesh firmness	PoliMi, (ATB), HES-SO
Pigment Analyzer	ATB	SSC, starch, (ethylene)	HES-SO, (ATB)
Raman	FBH	Cuticle main compound	FBH, (ATB)

* Laser scanner was operative later than field trials. Therefor no LAI was used for reference.
** Pseudo NDVI values were calculated based on RGB channels of common commercial camera instead of NDVI camera.

Based on first year field trials it was decided to cover half of the 0% ETP irrigation part, to reduce effects of precipitation (hopefully to obtain "stress" conditions). Analysis of canopy temperature data sensed during the 2015 first field campaign indicated slight water stress at the covered subsection of the rows with no irrigation. Based on this indication, the plastic was removed (1/6/2015) and irrigation was resumed with identical level of those for conventional irrigation (100% ETP). Canopy temperature that was sensed again month later in the second field campaign indicated that no stress exist that time (T canopy C° in Figure 2d, before and after removing the plastic).

As shown in Table 3, yield results for 2015, there were no significant differences of yield weight and crop loads, comparing all irrigation treatments including the parts were the soil was coved. It may that the slight stress only affected firmness and %brix. The more interesting important outcome of this field trials is that irrigation can be cutoff by 50%. Economically, as long as there is no water limitation, in Switzerland for example, it may sound not that important. Yet, it aroused the benefit/need for sensors and SDSS: the soil properties were not homogeneous, the existing irrigation system in the apple orchard may need to be re-setup differently, irrigation can be added at later stage at specific time point, and fruit quality may be obtained by controlled irrigation system based on thermal measures - canopy sensor (and fruit sensor). In the future, the last founding relating fruit qulity could contribute to successful yield production according to specification of the food industry such as sugar concentration.

Table 3. Yield's result 2015

Variante	Crop load	Yield	IR	Firmness
	(average of apples/cm^2 branch)	(Kg tree^{-1})	(% brix)	(kg cm^{-2})
0% ETP no response	4.50 a	17.17 a	14.76 a	8.53 a
0% ETP only rain	4.43 a	25.61 a	13.38 b	8.12 ab
0% ETP sensor response	4.67 a	23.06 a	12.67 d	7.85 b
50% ETP	4.63 a	21.01 a	13.20 c	7.61 bc
100% ETP	4.61 a	24.72 a	12.36 d	6.90 c
Farmer	4.13 a	20.45 a	-	-

In '0% ETP no response' soil was covered plastic during the hole summer and had limited water from precipitation and no irrigation. The '0% ETP only rain' had no plastic cover and water only from precipitation. The '0% ETP sensor response' had plastic cover that was removed after the 1st campaign and limited water. Then when the plastic removed it had no limited water from precipitation and irrigation. Additional results from field trials in Switzerland presented in appendix M.

WP7 – Demonstration

Fruit sensor were demonstrated to stakeholders in Switzerland at the end of harvest time during the last field campaign, September 2015 (Figure 10).

ARBORICULTURE

→ Agri, 18 Septembre 2015

De l'ingénierie pointue pour l'irrigation

Bernard Messerli

Prendre des décisions concernant l'irrigation et la date optimale de récolte. Etat des lieux dans le verger de Renald Pasche à Duillier, à quelques encablures de l'Ecole d'ingénieur de Changins (EIC) qui accueille les chercheurs d'Europe et du Proche-Orient.

Pour envisager un pilotage fin en matière d'eau et de cueillette, des ingénieurs, experts multidisciplinaires en provenance de huit pays (Israël, Grèce, Danemark, Turquie, Suisse, etc.), planchent sur la mise en réseau de données obtenues sur la plante par un matériel électronique sophistiqué: laser, spider, spectroscope et autres senseurs.

«L'idée, c'est de mesurer comment la plante perçoit les changements du milieu, comment le pommier modifie son comportement suivant l'irrigation: dans ce secteur, zéro, pas d'eau du tout (on voit des bâches en plastique sur le sol); là, 50% de l'apport mesuré par ETP (évapotranspiration potentielle) et ici 100%, c'est-à-dire l'irrigation normale». Le Dr Dominique Fleury insiste sur cette notion de lecture pointue de la plante. Ce professeur à l'EIC reçoit ses collègues allemands et italiens avec un enthousiasme communicatif. Au milieu d'un interligne de pommiers (Gala sur Pajam2) des arboriculteurs observent un aréopage de savants tous manipulant des caisses de matériel électronique dont les multiples guirlandes de fils rejoignent branchages et pommes.

Spider pour senseurs

Un pommier dégoulinant de fils aplatis semble imiter un sapin de Noël. Il s'agit plutôt d'une sorte de toile d'araignée (spider en anglais) dont chaque terminaison de fil abrite un senseur capable de lire la coloration de la pomme; information traduite dans un ordinateur pour le besoin de la recherche sur la maturité du fruit. «Les carotènes (pigment jaune-orange) qui augmentent et le vert de la chlorophylle qui se retire nous renseignent sur une évolution vers la maturité de la pomme», explique Jana Käthner, chercheuse au Département d'ingénierie horticole du Leibniz Institut de Potsdam. Le professeur Alessandro Torricelli, du Polytechnicum de Milan, Département de physique, préfère la technologie biomédicale du TRS (comme Temps Résolu Spectromètre); un appareil, dimension surligneur, dont le rayon laser revient avec un temps variable (en milliardième de seconde!). La fraction absorbée du rayon renseigne sur la composition chimique du fruit tandis que la partie diffusée informe sur la structure cellulaire... Tout cela en jouant sur le temps de réflexion de l'onde envoyée!

Fièvre arboricole mesurée

Avec la technologie de spectrographie Raman, le docteur Martin Maiwald, de l'Institut (en technique de hautes fréquences) Ferdinand Braun, de Leibniz, utilise un appareil diffusant des photons (particules de lumière) pour observer l'échange d'énergie entre le rayon lumineux et le milieu analysé (feuille ou fruit). But de l'opération: mesurer le stress de la plante. Le pommier souffrant (de manque d'eau, par exemple) émet une sorte de fièvre, de chaleur particulière que l'appareil peut mesurer et interpréter.

Résultats? «Impossible d'en fournir pour l'instant puisque le projet USER-PA (résumons l'acronyme anglais à Réseau de techniques de précision en agriculture) qui réunit universités, institut de recherches et industries, a débuté en 2014» (Fleury dixit). La rencontre visait plutôt à convaincre le monde de la production (arboricole mais aussi viticole) que si le changement climatique contraint à optimiser irrigation et récolte, la recherche est prête à offrir un soutien de qualité.

Jeanne Giesser, conseillère technique pour Léman Fruits, a montré sur le site pa-fmis.com comment, de la plate-forme réticulée, les données paneuropéennes pourront passer du satellite au praticien, avec toutes les adaptations régionales voulues. La mise en place d'un triaxal praticiens-vulgarisation-recherche vient rassurer... Et tempérer un peu la crainte de voir l'ingénierie de haut niveau avaler par le haut du ciel avec ses satellites, les gens qui arpentent, pieds sur terre ferme, vignes et vergers.

Jana Käthner installant un senseur du spider sur pomme pour observer sa maturité.

Martin Maiwald photonisant un fruit pour étudier son niveau de stress.

Alessandro Torricelli analysant, à l'aide d'un rayon laser, structure cellulaire et composition chimique du fruit.

Figure 10. Report on the demonstration, Messerli B. 2015. De l'ingénierie pointue pour l'irrigation. Agri 18 septembre. Pp 22.

Thermal imaging and FMIS was demonstrated during an international conference, the ECPA 2015 (July 16). The mobile platform of the UK team was demonstrated operatively with their own sensors during the closing meeting in HAU, January 2016. A demonstration as a whole unit performance involving the platform, sensors and FMIS altogether, while data acquisition in an orchard or vineyard was not carried out. Since no full demonstration was organized, a comprehensive map of stakeholders was not completed.

Nevertheless, it was reported that the project has made a substantial difference to the industry compared with before the project started. Media interviews, meetings with members with influential policy makers discussing and demonstrating the autonomous tractor locally in the UK, had led to additional funding streams for the development of further agricultural autonomous machinery.

WP8 – Project management

Consortium agreement (Deliverable D8.1.1 *ARO – Israel* and *all partners*) was signed at the beginning of the project. Table 4 lists all meetings that were held.

Table 4. Project meetings

Date	Place	Subject	partners
8-10 April, 2013	The Institute of Agricultural Engineering, Rishon-Le Zion,	Kickoff meeting	All (PoliMi connected by

	Israel		Skype)
14-15 January, 2014	FBH institute, Berlin, Germany	Annual follow up meeting	All
26 March ,2014	Tele conference, Skype	Last preparations of field trials 2014 Switzerland	ARO, ATB, CER./IRE. and HES-SO
24-27 June, 2014	Prangins (VD), Switzerland	Field campaign, Irrigation	All excluding FBH and ADU team
22-25 July, 2014	Prangins (VD), Switzerland	Field campaign, Irrigation and harvesting	HES-SO, ARO and ATB
1-5 September, 2014	Prangins (VD), Switzerland	Field campaign, Harvesting	HES-SO, ATB, PoliMi and FHB
20-21 January, 2015	AUA, Athens, Greece	Annual follow up meeting	All
22-26 June, 2015	Prangins (VD), Switzerland	Field campaign, Irrigation	HES-SO and ARO
1-2 July, 2015	Prangins (VD), Switzerland	Field campaign, Harvesting	HES-SO and PoliMi
14 July, 2015	The Institute of Agricultural Engineering, Rishon – Le Zion, Israel	FMIS web site	ARO, UCHP and CER.-IRE.
21-22 July, 2015	Prangins (VD), Switzerland	Field campaign, Harvesting	HES-SO and PoliMi
27-31 July, 2015	Prangins (VD), Switzerland	Field campaign, Irrigation and harvesting	HES-SO, ARO and UCHP
31 August-2 September, 2015	Prangins (VD), Switzerland	Field campaign, Harvesting and demonstration	HES-SO, ATB, PoliMi and PHB
25-27 January, 2016	HAU, Edgmond, Newport, UK	Closing meeting	All

All planed annual meeting were carried out and followed with *periodic summary of project progress after annual meeting*, *ARO – Israel* (Deliverable D8.1.2). Detailed meeting summaries and follow-up records are attached in appendix N1. The project was reported by various means of publication, by *most of the partners* (Deliverables D8.2s). Table 5 list all the publication that were done within the framework of this project.

Table 5. Project publications

Media	Partners	Subject / Title
Pres release and interviews: Radio, TV, Journal	ARO	Press release of project announcement in Hebrew and English (April, 2013). Rud R., 2015, Implementation of thermal imaging for irrigation using ground mobile platform, VolcaniVoice, 2(1): 25-31, http://www.tiktakti.co.il/catalog//volcani/2015-2-1.
	ATB	"Usability of environmentally sound and reliable techniques in precision agriculture (USER-PA) "Zude, M. (11.10.2013) Radio interview: Deutschlandfunk, Sendung Forschung aktuell, 16:35 Uhr http://www.dradio.de/aodflash/player.php?station=1&broadcast=9507&datum=20131010&playtime=1381416305&fileid=21fe68fd&sendung=9507&beitrag=2281890/&Käthner, J.; Kunzelmann, J.; Zude, M. (2014) Phytotechnology of Horticulture – Fruit Sensors. Lange Nacht der Wissenschaften, 10.05.2014, Berlin, GermanyKäthner, J.; Pflanz, M.; Zude, M. (2015). Phytotechnology of Horticulture – Fruit Sensors. Lange Nacht der Wissenschaften, 13.06.2015, Berlin, GermanyZude, M. (2016). Radio interview on precision horticulture, 15.1.2016, NDR, Sendung LOGO
	FHB	Confirmation by e-mail of project announcement (May, 2013).
	HES-SO	Fleury D. 2014. Nouvelle plate-forme européenne pour la gestion de l'irrigation en culture spéciales. Revue suisse de Vitic. Arboric. Hortic. 46 :77. Fleury D. 2013. Essai appliqués en robotique et agriculture de précision à l'école d'ingénieurs de Changins. Objectif 79: 15-17. Fleury D. 2013. Nouvelles technologies: l'agriculture de précision pour mieux gérer l'irrigation. Agri 21 juin. Pp. 14.
	HAU	www.youtube.com/watch?v=VaZL7v_7nNo www.youtube.com/watch?v=PmT5zuB7osw
Presentation at conferences, workshops, symposium	ADU	I. Bogrekci, P. Demircioglu, E.B. Kayhan, 2014, Mechanical Design and FEA Analysis for Vineyard Robot, International Conference on Production Research - Regional Conference Africa, Europe and the Middle East and 3rd International Conference on Quality and Innovation, July 1-5, CLUJ-NAPOCA, Romania.
	ARO	Asaf A., Alchanatis V., Rud R., 2015, Automatic mapping of vineyards water status using ground based thermal imaging, ECPA, 12-15 July 2015, Israel.
	ATB	Zude-Sasse M (2015): Keynote - Views on Precision Horticulture. 10th ECPA, 12-16 July, Tel Aviv, Isreal Zude-Sasse M (2014): Keynote – In-situ fruit sensors. International Workshop on Smart Farming, 11.08.2014, Kuala Lumpur, Malaysia Zude-Sasse M (2014): Keynote - Using data from in-situ fruit assessment to inform pre- and post-harvest management decisions. International Horticulture Congress, IHC, August 2014, Brisbane, Australia. Additional events in appendix N (closing meeting reports - ATB).
		Fountas, S. (2013): Keynote – Precision horticulture, 9th ECPA, 7-11,

	CER. /IRE.	Lleida, Catalonia, Spain. Fountas, S. Tsiropoulos, Z., 2014. The value of Farm Management Information Systems. Innovations in Agriculture, 2-5 February, 2014, Abu Dhabi. Fountas, S., Tsiropoulos, Z., 2013. Introduction to ICT project USER-PA. Novi Sad GEO Workshop, 18-21 September, 2013. Ζ. Τσιρόπουλος, Σ. Φουντάς, 2013. Software for mapping tractor properties. Greek Agricultural Engineering Conference, 25-26 September, 2013. Fountas, S., 2013. Precision agriculture applications in high value crops. Greek Horticultural Conference, October 15-18, 2013.
	HAU	Invited speaker to 13th Workshop on Systems Biology, 13th May 2016, Melbourne, Australia. Invited speaker UK Science and Innovation Network, 25 November 2015, British Embassy Beijing. Invited speaker to CIGR-International Commission of Agricultural and Biosystems Engineering, Beijing, September 16, 2015 Titled: The future of precision farming: Designing systems for the farm of tomorrow. Invited speaker, Preliminary Development of an Autonomous Orchard Tractor , At 10th European Conference on Precision Agriculture, Volcani Center, Risho-LeZion, Israel, July 12-16, 2015. Invited speaker ISTPA 2014 The Second International Summit on Precision Agriculture (ISTPA 2014) and CIGR 2014 (International Commission of Agricultural and Biosystems Engineering under The First International Conference on Smart Agriculture Innovative Development), Beijing, China. Presented a keynote lecture at the Fourth Congress of Engineering Loyola, COIL 2015 "Systems, Technology and Innovation", November 13 - 15 2015, titled: The Development of Robotics in Agriculture-work from Harper Adams, UK. Invited speaker: International Summit on Precision Agriculture, Beijing, September 11-15, 2014, Title: The future of precision farming: Designing systems for the farm of tomorrow
	PoliMi, ATB & HES-SO	A. Torricelli, D. Fleury, J. Giesser, R. Pasche, J. Kaethner, M. Zude, L. Spinelli,2015, «Nondestructive assessment of apple optical properties during growth by time-resolved reflectance spectroscopy in the orchard», the 3rd International Conference on BioPhotonics, 20-22 May, Plorence, Italy.
	PoliMi	A.Torricelli, D.Contini, A.Dalla Mora, E.Martinenghi, D.Tamborini, F.Villa, A. Tosi, L.Spinelli, 2015, «Recent Advances in Time-Resolved NIR Spectroscopy for Nondestructive Assessment of Fruit Quality», 9th Fruit, Nut and Vegetable Production Engineering Symposium Frutic Italy, 19-22 May, Italy.
Proceedings and Peer reviewed paper	ATB	Zude, M. (2015): Interaction of 3D soil electrical conductivity and generative growth in Prunus domestica L. European Journal of Horticultural Science. 80 (5): 231-239 Online: http://dx.doi.org/10.17660/eJHS.2015/80.5.5 Seifert, B.; Zude, M.; Spinelli, L.; Torricelli, A. (2015): Optical properties of developing pip and stone fruit reveal underlying structural changes. Physiologia Plantarum. 153 (2): 327-336 Online: http://dx.doi.org/10.1111/ppl.12232 Additional events in appendix N (closing meeting reports - ATB).
	FHB	B. Sumpf, M. Maiwald, A. Müller, F. Bugge, J. Fricke, P. Ressel, J. Pohl, G. Erbert, G. Tränkle, “ Red emitting monolithic dual wavelength DBR diode lasers for shifted excitation Raman difference spectroscopy”, Photonics

	West 2014, Proc. SPIE 9002, Novel In-Plane Semiconductor Lasers XIII, 900208 (27 February 2014); doi: 10.1117/12.2035487
PoliMi	Alessandro Torricelli, Davide Contini, Alberto Dalla Mora, Edoardo Martinenghi, Davide Tamborini, Federica Villa, Alberto Tosi, Lorenzo Spinelli, 2015, Recent Advances in Time-Resolved NIR Spectroscopy for Nondestructive Assessment of Fruit Quality, CHEMICAL ENGINEERING TRANSACTIONS, 44:43-48.
PoliMi, ATB & HES-SO	Alessandro Torricelli, Jana Kaethner, Manuela Zude, Dominique Fleury, eanne Giesser, Reynald Pasche, Lorenzo Spinelli, 2015, Nondestructive assessment of apple optical properties during growth by time-resolved reflectance spectroscopy in the orchards, BioPhotonics

Dissemination and exploitation *ARO – Israel and All* (deliverable D8.3s) was partly achieved. The expected outcome of an integrated system that incorporates a number of sensing techniques and a web based FMIS that enables farmers to manage their crop was ended with demonstration of canopy - fruit sensor and FMIS. It expressed the potential of providing farmers quantitative information to decide upon the optimal harvest timing and irrigation, while fruit quality and the production remained effective.

Partners' comprehensive collaboration during field campaigns performed as project inter-workshop and led to integration and assimilation of sensor data into FMIS. Since a complete prototype using the converted tractor with the canopy and fruit sensors for optimal irrigation and harvest timing was not tested in the orchard, no external workshop was organized. The concept was presented to stakeholders while demonstration in the end of field trials in Switzerland, and through up development stages of the mobile platform in UK. Beside the web based FMIS (http://pa-fmis.com/ last accessed on January 24, 2016), a web based data transfer was constructed for fast data sharing, USER-PA portal (http://pa-fmis.com/user-pa/login.aspx last updated on July 26, 2016) and the public project information was presented on USER-PA information website (http://user-pa.ag-fmis.com/wordpress/ last updated on July 20, 2015).

5. Summary

Two main gaps in precision agriculture were identified that this project was approaching to abridge: 1. Reliability - insufficient reliability for everyday use in harsh conditions, and limited robustness of calibrations. 2. Usability - techniques were applied as isolated approaches without synergy of sensors' data. The objectives were: (1) to establish and develop technologies to sense, acquire, analyze and present to the farmer information that will enable him to manage the crop more efficiently and with reduced environmental footprint; (2) evaluate the economic advantages of USER-PA for the farmers, and its environmental impact for greener agriculture; and (3) demonstrate the capabilities of USER-PA.

As for the 1st objective, the project led to additional local activities, using, continuing and establishing sensing technology and spatial information processing. It aroused awareness to efficient resource use, even just by being a part of USER-PA team. The 2nd objective, economical evaluation of USER-PA, was achieved and assessment of USER-PA was presented. This result is based only on data from one site, thus should be used with respect to this limitation. It pointed out that USER-PA will be more efficient in high risk agriculture areas, in semi-arid zone, rather than in temperate places like Switzerland. Nevertheless, USER-PA result with very clear conclusion to reduce irrigation in the experiment site without jeopardizing fruit quality and yield level. The implications is that irrigation protocol should be revised or more precisely established. We believe that in the future decisions will be based on some sensing measure.

The 3rd objective, demonstration, was partly achieved. There is still work to be done. Two years of testing agro technology, involving with seasonal cycling of growth periods is just a beginning. There is a need for longer period than what was given within the project framework, for reliable calibration of canopy and fruit sensors. It contributes greatly to limited demonstration and less attraction of stakeholders. The framework of no central finance control might have contributed to partial achievement of the 3rd objective.

Collaboration and establishment of links led to the most pronounced agronomical outcome: a better exploitation of water while keeping the environment cleaner from chemicals. Efficient exploitation of water resources will reduce the crops water foot-print and drive to a sustainable management of this important natural resource. An information to decide upon the optimal harvest timing will help to increase the quality of fruits while the production will remain effective, competitive and profitable.

"… now we can start", as one of the partners stated at closing meeting.