

## **Developing and evaluating a telemetry system to monitor pesticides practices**

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### **Abstract**

In the last years the sustainability, traceability and more generally, the precision agriculture approach, are embracing by farm companies. Many are the technological and available solutions ranging from cheapest and simple sensor to complex satellite systems. Inside these “Smart Systems”, the telemetry appears an emergent and useful technology that could improve the efficiency of farms management. In this study, a preliminary implementation in a wine farm, was done. The overall objective was the monitoring and optimization the entire wine chain from vineyard to the bottle. In particular this paper focuses on the pesticide practices stages. The study performed examines the telemetry as tool to monitoring, in real time, the farm vehicles and

equipments in the working day, in order to make available data to the technical management. Two were the main elements of the system: a farm tractor coupled with a pneumatic sprayer and a Web-GIS server platform. The hardware was made of sensors to detect the signals coming from the tractor and the sprayer, a GPRS receiver to locate the position and data sending remotely. The trackable tractor parameters were related to operative condition such as forward speed, P.T.O. status, working times, three point hitch level and vehicle inclination. About the sprayer instead, two were the main checks i.e. the liquid flow rate and the properly functioning of the single hydraulic plant sections (open-close). The achieved data related to position, routes and activities performed by farm vehicles were stored in a the Web-GIS platform Agrisystema. The latter provides an identification and permanent recording of desired query related to field or winery. All this data and their own information, can be viewed constantly through a CAD-GIS dashboard Agròs where the main productive process indexes were outlined. The preliminary results showed the feasibility of this system and the usefulness as decision support system for the farm management.

## **Introduction**

Pests control is strategical stage of the agricultural production chains. In this regard the law requirements introduced by Italian Legislative Decree 150/2012, transposition of Directive 2009/128/CE, has led relevant changes and challenges. The mitigation of wrong way to acting and the generalized diffusion best agricultural practices can be achieved either improving techniques, technologies and the support infrastructures either by increasing the knowledge of the main player that is to say farm managers and workers. The technological innovations, comparable with precision agriculture, are able to provide optimal solutions in order to get agricultural sustainable practices. A lot of studies carried out in the past have been translated into precision farming solutions as those so far commercialized by big companies such as Agco, John Deere, Dikey-John etc. The generalizations of the precision viticulture management techniques is as already discussed from many researchers, a problem of economical resources and knowledge (Reichardt 2009, Vaculik

2008, Boncinelli *et al.*,2010). However, a further aspect is the compartmentalized vision of the single issues by farm: the adoption of a technology to enhance an operative stage often does not cover the complexity knowledge of the process and the variables, which determined the need for an aid instrument (Vieri *et al.*, 2010, Vieri *et al.*, 2012). The markets variability and the increasingly intensive competition from emerging countries, requires on the farms the promptly and constantly monitoring of their productive and economic - financial performance. This goal involves the overall real-time knowledge of the processes, data mining and the subsequent processing of the information in a clear, intuitive and quick manner. Nowadays this is implemented in the industrial sector through the companies dashboard, a system of organized indicators, that can be queried on the PC in order to inform and guide the managerial area to take more efficient decisions. However, the monitoring of the agricultural processes is characterized by a more complexity due to the spatial dispersion of the activities than the industrial sector where the production processes are confined to a production unit. On these basis can be perceive the importance of multi-parameters monitoring tools on Web platform such as the dashboard cloud Agròs ([agrismart.eu](http://agrismart.eu), 2015). It is a decision support tool i.e. a set of hardware and software aids for remote monitoring of critical mechanized operations (input reduction and environmental risks). Cloud tool allows multiple levels of configurability to monitor, track and quantify all the resources flows used in business management. One the great issues encountered at the farm level is the monitoring of the pest control stages. In a perspective of process optimization, the proper practices should be based on:

- meteorological data acquisition;
- identification of the ideal timing of intervention by means of predictive models;
- methodologies to define doses and appropriate volumes in relation to the target features;
- variable rate technologies;
- remote monitoring systems.

In this complex framework, the related risk, is the obtaining of the decision support data at slower speeds than the actual requirements. In the last decade some studies have highlighted the usefulness

of telecommunication technologies such as GSM/GPRS, RFID to improve the data collection efficiency and precision agriculture (Castillo-Ruiz *et al.*, 2015, Lifeaware.org, 2015, Tseng *et al.*, 2006 ). The telemetry is an example of ICT technology that can allow the measurement and transcription of information to the technical manager or worker itself in real time. This technology, initially developed for automotive tracking, is today employed in many types of vehicles i.e. motorcycle, boat or fleet to track position and a wide range of data. The telemetry system, applied to the agricultural machine, is today configurable differently depending on the business needs. In this regard, it seems interesting to distinguish between the standard monitoring of the machine work, performed to check the functional control and maintenance of the vehicle, to the productivity of the work done, such as is already occurring on the combine harvester with regard to the assessing the yield, cleaning and moisture of the collection. Another innovative aspect is the interfacing of the collected information with geographic maps georeferenced in real time way, allowing the so-called “fleet control” through a GPRS module on the machine. This enables for instance the optimization of the yard logistics and the maintenance phases and also to show the crop that has yet to be harvested and to maximize the work planning of the following working days of the machine. The displaying of technical and operational data is provided by software support available via the Internet on Google Earth. In the pest control stages, some shared challenges between winegrowers are the assessment of sprayed quantities and their distribution across the vineyard but also the ability to create records of work sessions. About this, only few studies have addressed these aspects and developed solutions such as the Project AWARE in 2009 (Lifeaware.org, 2015). Currently the market does not offer solutions for this specific purpose. Overall, solutions to precise vehicle tracking, are recognized to be essential tools to achieve efficiency. These systems lead a complete knowledge of the pesticide practices and at the same time, enabling prompt actions reducing costs and improving sustainability. On this framework the aims of the work were the integration of the overall vision of pesticides management issues, focusing on the feasibility of the telemetry as a tool

for the monitoring of the pesticides spraying. The first implementing and trials were made with low-cost and scalable functionalities.

## **Materials and methods**

In order to understand the feasibility of such systems, in the 2014 growing season a telemetry system coupled to pneumatic sprayer Cima Blitz 55T was implemented fig.1 . The activities were devoted mainly to measuring a sensitive number of data for the spraying operations and their remotely delivering to the farm supervisor.

The study areas were located at Castellina in Chianti into the Castello di Fonterutoli Mazzei Farm vineyards, in the Siena province. The farm covers a surface area of 650 hectares, of which 117 are devoted to specialized vineyards, divided between five localities included in an area of 10 km: Fonterutoli, Siepi, Badiola, Belvedere and Caggio, located at between 230 and 500 meters above sea level and exposed to the south and southwest. All the field tests were performed in vineyards (mainly cv: Sangiovese) trained to a horizontal spur-cordon (4-6 per spur), at 0.8 m height from the ground; planting distances were 2.20 m between the rows, and 0.9 m between the vines.

The system was made up of the following main elements:

- a farm tractor coupled with a pneumatic sprayer equipped with a communication and location intelligent unit CLIU a GPRS unit and spraying sensors;
- a Web-GIS telemetric server platform at [www.agrysystema.com](http://www.agrysystema.com);
- a CAD-GIS mobile software Agròs for data farm management;

The embedded hardware was made of sensors to detect the signals coming from the sprayer and the tractor. For the sprayer two were the main checks i.e. the liquid flow rate, made by a flowmeter ARAG, and the properly functioning of the left/right sprayer arms (opened-closed) through two pressure sensors. The properly measurement of the filling stage was gathered by a digital flowmeter placed on the water pickup point in the mixturing area of the farm. This information is the indirect checking feedback of the spraying phases. The brain of the system was a communication and

location intelligent unit CLIU specially engineered to allow the widest connectivity with external devices.

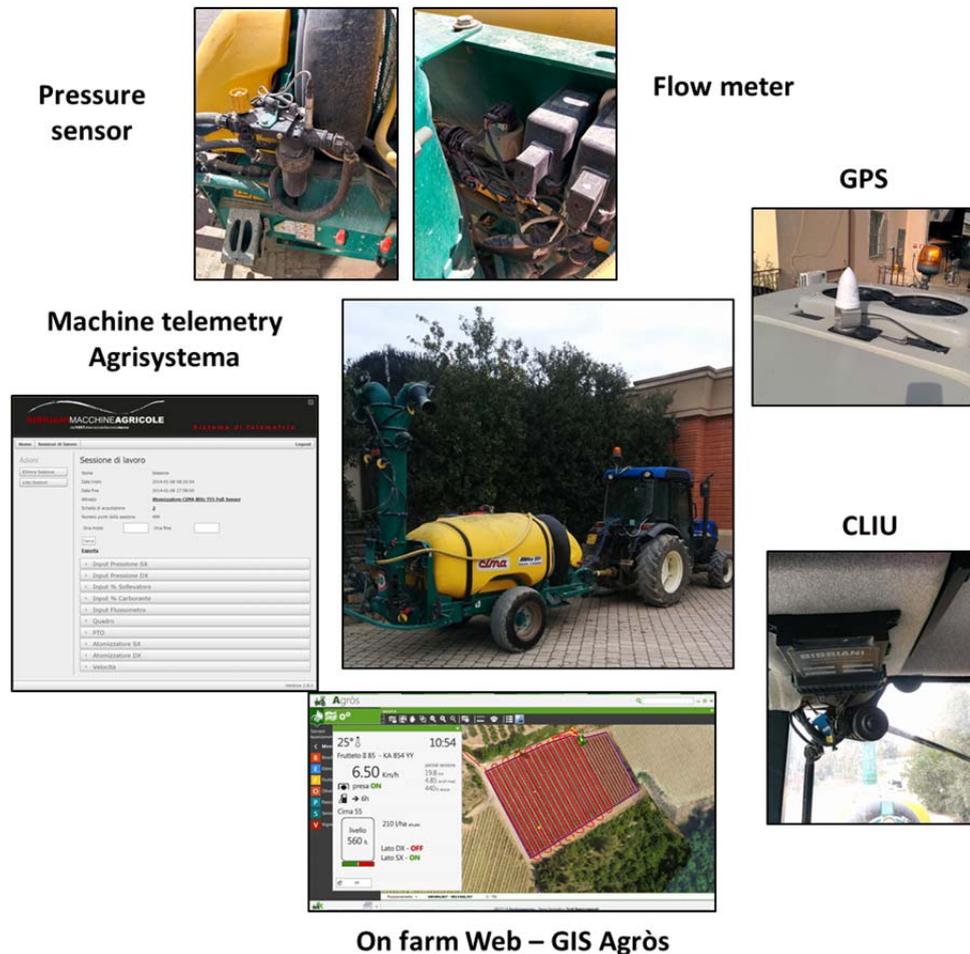


Figure 1 General overview of the telemetric system implemented

This terminal integrated a GSM (Global System for Mobile communications) a GPRS (General Packet Radio Service) radio system a DGNSS (Differential Global Navigation Satellite System) and a set of digital and analogic I/O. This was responsible to initialize and communicate with all other devices or sensors, acquire data and send them to the server according to a dedicated protocol. All the acquired data were temporarily stored to a buffer consisting of non-volatile memory of 2 GB in size, in order to avoid information losses in case of low coverage by the GPRS signals. A GSM cellular network integrated sending data packets every 15s to the server. The inputs provided are the following: 8 digital inputs, 2 analog inputs for pressure sensors, 4 analog inputs to monitoring three

hitch point level, PTO status, fuel level, free channel and 2 inputs for flow meter. The system is also equipped with two outputs for controlling external relays, an input serial port for signals coming from external antennas such as DGPS or RTK and an output serial port for other types of connectivity. The second element was the server Agrisystema fig.2.

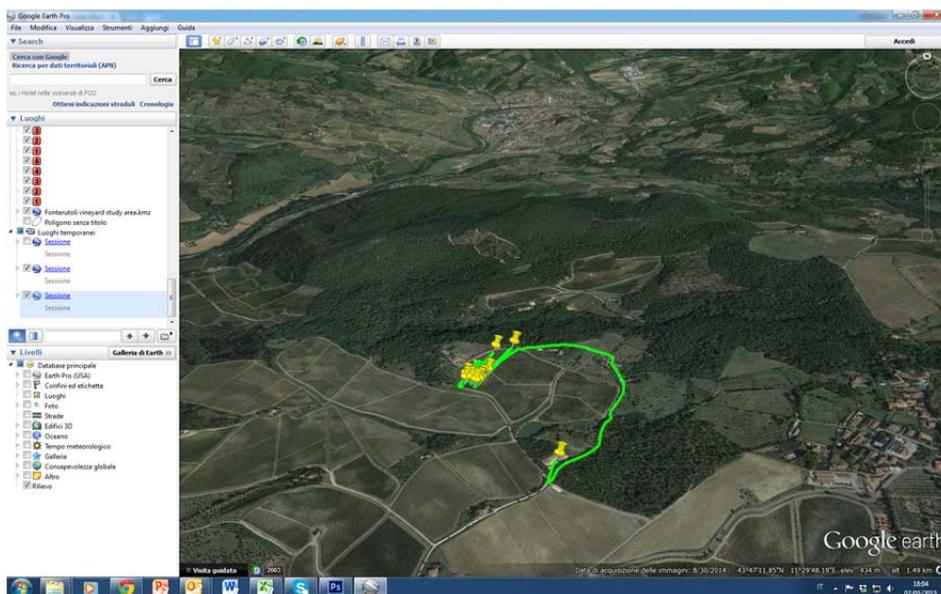
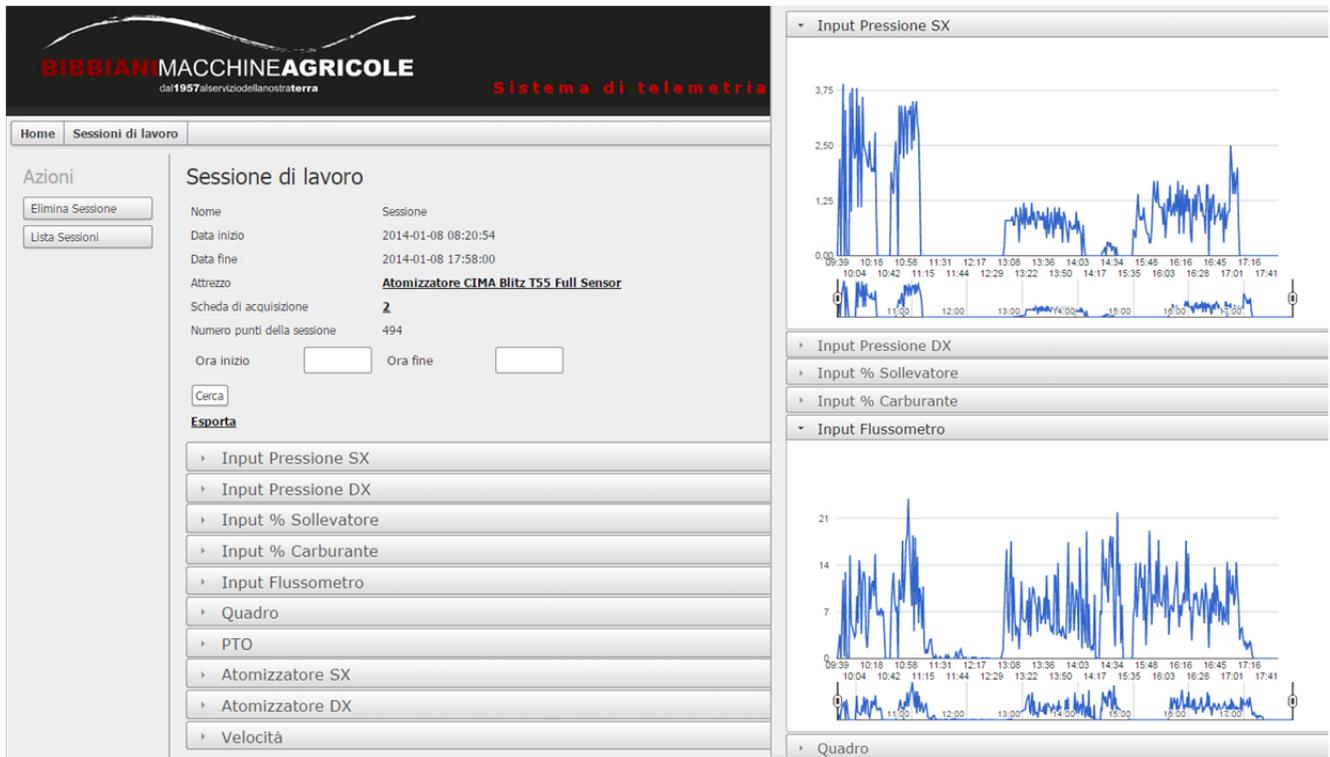


Figure 2 Telemetry interface: some print screens of the main windows

This was aimed to recording the overall trackable tractor parameters i.e. trajectories, forward speed, P.T.O. status, working times, three hitch point level, vehicle inclination and to process it. The server

accomplish the data fusion, viewing, storage and the downloading. Moreover, the server was implemented with a Web Geographical Information System (Web-GIS) and enables the Keyhole Markup Language KML file creations trajectories which, in its turn, permits the showing on GIS viewers. The collected data were archived in the CAD-GIS mobile software Agròs fig. 3.



Figure 3 The CAD-GIS mobile software Agròs for data farm management

This software enables additional data storing such as amount and type of active ingredient employed, liters of water, their quantity in relation to the plots, pre harvest interval of the pesticides. A section was related to workers including their habilitation to spraying pesticide and validity term. Also the fuel consumption of each yard was monitored and stored. All this results in knowledge improving of the annual management of raw materials employed in the productive processes leading greater economies of scale. To ensure adequate comparison, the pneumatic sprayer at the beginning of the season was cleaned and calibrated on the Mazzei's farm specifications. Furthermore a conventional database which were stored the main information (date, dose/ha, active principles, sprayed vineyard, timing etc.) made by a person in charge was done. In order to assess the CLIU some trials were performed aimed to evaluate the relationship between telemetry system and on field measurements.

## Results

Twelve spraying stages were recorded with a temporal resolution of 15s in the season 2014. The resulting data, visible on the web server agrisystema, were used for a first evaluation of the implementation. The acquired data, were processed and organized in an intuitive manner. As showed fig.2 in the initial page there was the selection of the farm yards with their general identification codes. Once selected, all the related information were displayed in another window: everyone of the monitorable parameters (sprayer and tractor) can be queried and graphical reported in real time way or in post processing analysis. Overall, the system allows a continuous and timely acquisition of information. Only in areas characterized by poor GSM signal or in vineyards under canopy coverage in two spraying stages, there were data losses respectively 7 minutes on a working session of 68 and 4' of 56' probably due to a temporary crashing of the buffer. This problem has also been noticed in the road journey covered by trees where maximum errors around 5 m were detected. However, further studies are necessary to improve the performance of the position tracking in areas characterized by high orographic variability and poor GSM signal coverage. These issues have been partially resolved through the use of more performing antennas. About the correlation between tuning of the sprayer (volume l/h) with those acquired by the system CLIU a correlation of 0.92 Std. dev. 0.03 was reached. Equivalent values about the correlations relatively to the forward speed compared to manual measurements taken in the field were measured. The employment of two pressure sensors included in the left and right spray arms was in tune with the aims to monitoring the sprayer status. Indeed by analyzing the routes, a clearly identification of the starting and ending spraying points near the headland alley and at terminals rows, was found.

## **Conclusion**

The pursuit of the objectives set by the European Directive 2009/128/EC on the sustainable use of plant protection products requires the implementation of solutions to optimize the pesticides usage. In this context the adoption of precision viticulture techniques represent an effective decision support tool. The telemetry appears an emergent ITC technologies which could be useful to this challenge. The preliminary results have shown the chance of telemetry as management tools for the

pesticides spraying practices tracking. The system set up enabled the real time monitoring of crop protection steps. This information were either a useful tool to assess the work, either the basis for a database creation to verify and optimize the future planning. Overall the system enables a complete knowledge of spraying stages, therefore this could be a useful tool for the farm technicians allowing a reduction of on-site inspections, travel and consequently time and costs. Furthermore, the system replaces the manual data storing that many times, leads losses of information. Further developments will be the implementation of simple visualization on board device which will allow an intuitive check of the parameters by workers, in order to intervene promptly with the right corrections. Finally studies are required to identify new types of flow meters based on "no contact" technologies since the available agricultural solutions have shown continuity problems.

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## References

AgrismaRT.eu. 2015 Available online: <http://agrismart.eu/activities/cruscotto-cloud/> Accessed:June 2015.

Bonicelli, B., Naud, O., Rousset, S., Sinfort, C., De Rudnicki, V., Lescot, J. M., Ruelle, B., Scheyer, L. and Cotteux, E. (2010). "The challenge for precision spraying." Proceedings of "International Conference on Agricultural Engineering AgEng 2010", 6-8 September 2010, Clermont-Ferrand , France, (ISBN 13 : 978-2-85362-684-2).

Castillo-Ruiz Francisco J., Pérez-Ruiz Manuel, Blanco-Roldán Gregorio L., Gil-Ribes Jesús A., Agüera Juan 2015 Development of a Telemetry and Yield-Mapping System of Olive Harvester. Sensors 2015, 15, 4001-4018; doi:10.3390/s150204001 ISSN 1424-8220

Lifeaware.org 2015 Available online: [http://life\\_aware.teledetection.fr/web/index.php?lng=fr](http://life_aware.teledetection.fr/web/index.php?lng=fr)  
Accessed: June 2015.

Reichardt, M., C. Jürgens, et al. 2009. Dissemination of precision farming in Germany: acceptance, adoption, obstacles, knowledge transfer and training activities. *Precision Agriculture* 10(6), pp. 525-545.

Tseng, C.; Jiang, J.; Lee, R.; Lu, F.; Ouyang, C.; Chen, Y.; Chang, C. 2006 Feasibility study on application of GSM-SMS technology to field data acquisition. *Comput. Electron. Agric.* 2006, 53, 45–59.

Vačulik, A., Bonicelli. B., Palagos B., Laplana R. (2008). Réduction des pollutions des eaux par les produits phytosanitaires agricoles. Premiers enseignements d'une enquête auprès de professionnels européens. *Ingenieries*, 15 pages

Vieri M., Spezia M., Pagni P. P., (2010): Ingegneria delle produzioni viticole: stato dell'arte e future applicazioni. *Review n. 11 – Italus Hortus* 17 (1), 2010: 33 – 57 ISSN: 1127-3496.

Vieri M., Perria R., Rimediotti M., Sarri D., Storchi P.(2012). The New Architecture in the Vineyard System Management for Variable Rate Technologies and Traceability. *Proceedings of the I International Workshop on Vineyard Mechanization and Grape and Wine Quality ISHS Conference Piacenza 26-29 giugno 2012. Number 978 ISBN 9789066052093 ISSN 0567-7572*