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Embedded NICT* tools and traceability to control phytochemical treatments

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*New Information and communication technologies

Abstract

In France the concept of precision farming is a topical subject in relation with the "Grenelle environment" round table process and the Ecophyto 2018 plan. If the increase of productivity is one of its improvements, the reduction of the environmental impacts is another very important objective. New technologies of Information and Communication (NICT) allow responding to this challenge of quality. These technologies give solutions to manage pesticide applications thanks to the field work assistance tools and allow continuous monitoring and recording of the field operations to implement traceability and automatic field logbooks. This communication present the results of LIFE AWARE & TICSAD projects based on embedded NICT. We will approach the possible tracks allowing the management of news methods of treatment.

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1. Introduction

Water pollution caused by pesticides is one of the biggest problems facing aquatic ecosystems. To improve water quality, it is necessary to asses the impact of agricultural practices on the environment.

In France, studies conducted by IFEN (French institute for the environment) revealed that both surface and ground waters exhibit some significant contamination characteristics. In particular, 49% of surface water sampling locations were of average to poor quality and 27% of ground water sampling locations would need pesticide elimination treatment in order to provide acceptable drinking water.

Different studies [7] show that some pesticides residues are found in finished vine. 40% of them concerns anti botrytis and mildew at the average scale of 10 to 90µg.

The Water Framework Directive commits Member States to achieve "good" ecological water status for their water bodies by 2015. Pesticides are one of the causes of this deterioration.

The objective of the French Ecophyto 2018 plan is to reduce by half the use of pesticides before 2018. Vine growing without the use of pesticides would be utopian. The treatments will be always necessary whatever the product and the methods.

Within this context, Cemagref has been carrying out studies since 2000 to show how environmental pollution could be mitigated through: the optimisation of pesticide application techniques using NICT technologies, the implementation of inside plot of land operation traceability and through training campaigns that aim to increase awareness of stakeholders in sustainable viticulture. The two last studies aiming to these objectives are the Life AWARE [1] followed by the TICSAD [8] projects.

One of the objectives was to link the quantities of pesticide product spread during treatments with those found in surface water. Consequently an assessment of product distribution on the plants, soil and air during and after application is essential in order to establish the link between pesticide use, pesticide reaching the vegetal target and pesticide contamination of surface waters.

1.2. The context

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Vine sprayers are operated with air assistance that improves pesticide penetration within the canopy but on the other hand transports droplets to the air or onto the ground. They are often hydraulic or pneumatic machines that work along 2 to 4 rows. Different variables come into play during treatment to limit treatment to targeted vegetation: nozzle orientation, cleaning and maintenance of sprayers between treatments, flow rate settings (outlet rates according to volume/Ha sought and dosage/Ha).

The first objective is to measure spray losses during spraying operations. Field measurements [2] measuring ground and air spray losses for different spraying systems showed sizeable losses that varied according to the machine used and vegetation growth stages (soil losses: 7 to 15%, air losses: 14 to 45% depending on vegetation volumes).(Fig1)

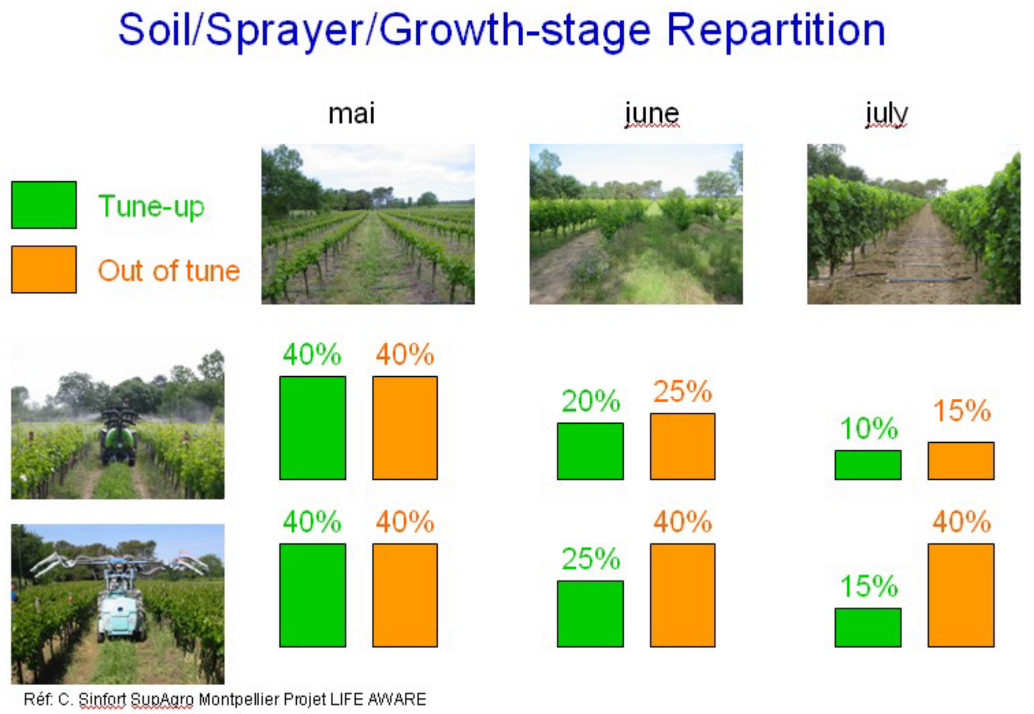

Figure 1:Soil / sprayer / grow stage losses repartition for each type of machine (© Cemagref 2009) (ref: SupAgro Montpellier 2007 C. Sinfort [2])

The monitoring of farmers' activities showed that with the type of existing machinery, it is very hard and tedious to adjust sprayers for each treatment and even more so when moving between 2 fields (treatment passage from 2 to 3 rows or change of row span). Most cases of plant-health product over-and-under dosages during treatments are due to incorrect settings or poor maintenance of sprayers.

The second objective is to improve a new NICT embedded technology helping the farmer to optimize the settings of the sprayer and to have a back-up of their work in order to improve their practices and reduce environmental impact.

This TICSAD project, that is a continuation of AWARE, is running to this day, geographically encompassing land areas from Bourgogne to Languedoc, with 20 winegrowers equipped with the new NICT TICSAD system. This new system takes into account the improvements enacted by the users of AWARE. By studying how the farmers use the system, we optimise their practices. The goal is to improve the system and improve its robustness. A secondary aim is to also teach the users the new NICT tools and methods to improve operating practices; different levels of students tested the formation based on the system and the software. The embedded system is going to be robustly tested and finalized during this project before it can be transferred to an industrial firm.

1.3. Inventory of on-board NICT systems

There are different devices such as calculators and/or regulators (Land Manager from Dickey-John, Spraymat from Muller Elektronik, Genius from Agrosystem, RDS Delta de RDS etc.), which enable measurement, and in certain cases, recording of treatment related data for cereal crop sprayers. However, they are generally cost prohibitive or unsuitable for vine and fruit tree sprayers. When compared to the cost of the sprayers used in viticulture and arboriculture, they are overly expensive. In addition, they do not satisfy the vine or fruit growers requirements in terms of continuous machinery monitoring based on simple parameters (right, left or partial flow rates, tank level, nozzle clogging detection, plot surface covered etc.) nor to adjust settings on a daily basis: (pressure & flow rate settings) nor to check nozzle performance, nor to transmit recorded date for simple traceability and analysis.

2. Material and methods

The systems, which we describe in this study, meet the need for pesticide reduction adapted to this form of agriculture by facilitating sprayer settings and the collection of objective data required to optimize plant health product treatments with the help of analyses realised by the added software.

2.1. The embedded equipment

The onboard system measures and records, second by second, product application parameters (flow rates, volume, meteorological information), which are geo-referenced using GPS technology. The system architecture is comprised of **treatment software** and **embedded equipment** linked with the software by USB flash drives or WIFI network (Life AWARE only).

The embedded equipment (Fig 2) includes an embedded electronic computer unit fitted on the tractor (**MPU**) and one more on the sprayer (**APU**) as well as measurement sensors

Figure 2: tractor – sprayer equipment, the tractor MPU © Cemagref 2009

The electronic **MPU** integrates acquired data management, Media data transfer, GPS-based geo-referencing, the weather station, data display and the Human Machine Interface as a very user friendly design providing pull-down menus similar to those used on mobile phones to guarantee easy usage and to counteract potential dangerous situations.

The electronic « **APU** » manages the acquisition of treatment-related data of the sprayer.

The system is designed so that the farmer has **no extra constraints, or operations to conduct during treatments**, which means that if a fault occurs, spraying operations do not have to be halted.

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Figure 3: electro magnetic flow-rate meters © Cemagref 2009

Figure 4: Tank level sensor © Cemagref 2009

Figure 5:On board IHM system © Cemagref 2009

Figure 6: weather station © Cemagref 2009

Consequently, the parameters measured are: left and right flow rates, tank level, supply pressure, meteorological information (wind speed and directions, temperature & humidity) and GPS positioning. This Ultrasound static « marine » type measurement station is free of all mechanical problems. The electro magnetic flow-rate meters tested are not affected by clogging due to sticky or powder products and do not depend on pressure-based measurements of tank residues (circuit purging and rinsing). An ultrasound sensor measures the tank level with a especially corrected treatment,.

The onboard systems have 3 roles:

1. **Prior to application**: **Assist the winegrower** during sprayer tank filling (direct and accurate reading of tank level), by allowing him to easily set flow rates based on plot parameters (row spacing, volume/Ha etc.). Weather information (wind speed <19km/h and humidity levels) allow for better product applications. Verify product from among those listed and set or change quantity levels.

2. **During application**: **Continuously visualize** machine operation parameters during plot treatment i.e. monitoring. This allows the winegrower to detect malfunctions (clogging, unbalanced spraying, tank residue levels, etc). Plant-health product traceability is facilitated by GPS referencing.

3. **Post treatment**: Transfer and then automatic generation of **treatment logs**. Inter plot traceability is rendered possible as the GPS module can differentiate vine rows of plots. Allows a fine interpretation of the quality of application.

Before beginning the work, the winegrower initialize the work at the workstation PC with the programmed USB key, (using the software TICSAD) so he can verify the list of tasks, the settings of the sprayer and each product used. He chooses the task he has to do and, once the tractor is running, the GPS module of the onboard system synchronises itself so that when the winegrower arrives at the plot of land he starts manually the record of data. At the

end of the designed plot, he stops manually to record and can then select the next registered task.
The default mode of the onboard system displays flow rates and tank levels for application monitoring but the grower can choose other options if required, e.g. Volume per hectare with ground speed or weather measurement (wind speed, temperature and humidity). The farmer can program phyto-chemical treatment tasks and also every other task required, like land measurement, tillage, topping and others with geo-referenced ways.

2.2. The traceability software

Traceability data are collected (low rates, tank levels, weather information), analyzed and then compared with winegrowers declared data, to provide farmers with strategies designed to improve their practices. The treatment software aims to prepare the fieldwork and to treat the measurement's data issued from the embedded system to generate an automatic field logbook report.

The software permits to configure the list of plots of land, the tools (sprayer and others), the users, the products for each treatment and the different tasks. Thus, the farmer prepares the work, which will be transferred with a configuration file using the USB key.

After work, the data are collected from the USB key to the database which collects and processes received data (trajectory computations and merging of machine data) and generates:

- Treatment analysis results related to plots treated and application dates.
- The traceability of realised work and geo-referenced quantities of product used.

2.3. Processing of treatment product data

A geographical information system (GIS) was deployed to create, collect and then represent the entire set of data: define wine-growers plots, plant health products applied, materials etc. so that maps and spatial analysis of each plot be analysed. (Fig 7)

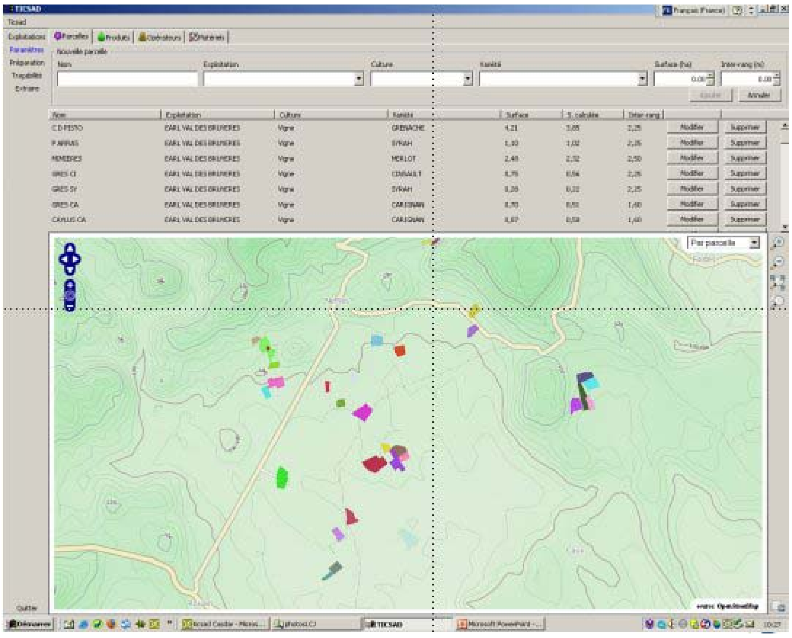

Figure 7: View of the list of wine plots of one winegrower with the TICSAD software © Cemagref 2009

The information recorded, second-by-second, includes: GPS (metric) sprayer positioning, left/right flow rates, volume of mixture tank residues and weather conditions (temperature,

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hygrometry, wind speed and direction). Information related the each parcel is extracted from each treatment event using a Geographical Information System (GIS). Cross-referenced analysis of the data is performed to derive essential criteria to assist decision-making.
All available data show that scientific study of the pesticides application can be conducted in-depth.

2.4. Generation of Plot Log

In relation to its role in application quality assessment, the system generates, in graphical form (Fig 8), plot related results where measured parameters, or those issued from computations, are displayed (Vol./Ha, wind speed /direction). A written report (Fig 9), providing information on different parameters, is also generated: commonly used sprayer settings, measurements, surface area treated, number of rows, dosage levels applied etc.
The data once treated summarize results in treatment sheets in which information provided by the winegrowers are compared with those objectively recorded by the system.
Data processing automatically generates a plot log and an automatic field logbook. That can be modified to satisfy related representations of this kind of information as well as sustainable agriculture specifications like those of TERRAVITIS.
The aim is to provide the winegrower easy to use information that can be instantly understood.
Other parameters can also be presented in graphic formats like wind force or humidity to enhance analysis.
Once all the data have been gathered, they are communicated to farmers via a data-exchange intranet site in an educative format designed for easy interpretation. The data can be visualized, interpreted and changed to improve the practices.

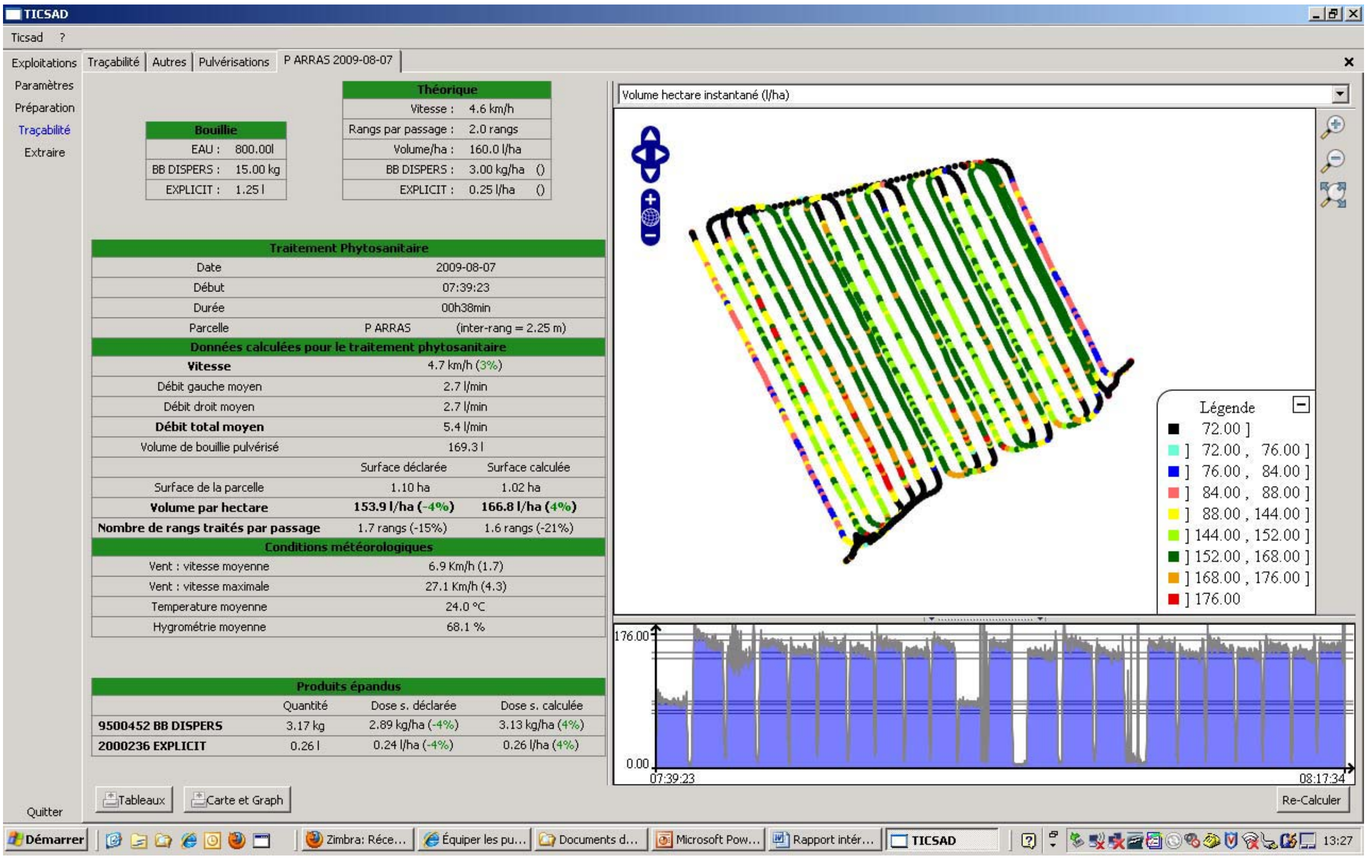

Figure 8: Representation of inter-plot treatment & treatment log © Cemagref 2009

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3. Results

The results of these projects concern the reduction of pesticides found at the outlet of the catchment's basin, reduction of product quantity used only thanks to the NICT tools help and the ways NICT gets to analyse and improve current practices.

3.1. Analyses of the current practices

The processing of treatment product data with the NTIC TICSAD system permits to analyse the farmer's practices and to extract the most current errors that conduct to bad results. We computed the practices of 20 farmers for one year that represents approximately 500 treatments.

We observed that only 68% of the treatments correspond to the amount envisaged by the farmer (Fig 12). The first error comes from a bad knowledge of the true surface of plots but also from coarse calculation errors of the amount during the preparation of the sprayer.

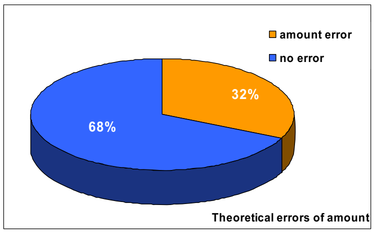

Figure 9: Percentage of treatment with bad amount © Cemagref 2010

The first reason that conducts to losses and bad treatments is out of tuned apparatus like that unbalance slope or bad speed use (Fig 10). The result is some important variations of quantity by hectare applied that represents 20% of all the treatments.

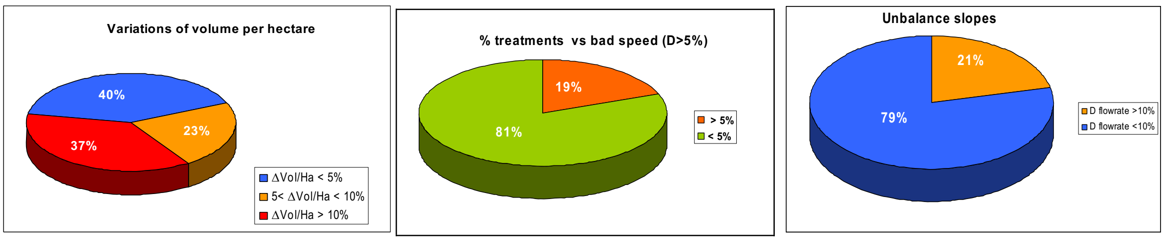

Figure 10: percentage of errors conducting to bad treatment © Cemagref 2010

Another result concerns the weather conditions during the application (Fig 11). For a good treatment, the temperature must be ranging between 12°C and 20°C while moisture must be between 75 and 95%.

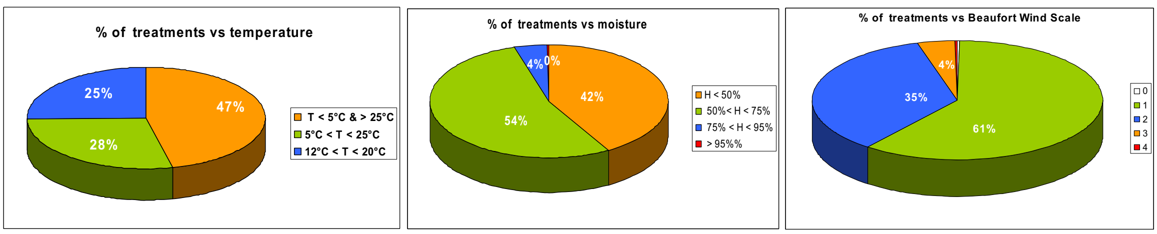

Figure 11: Weather conditions analyse © Cemagref 2010

The results show that less than 50% of the treatments are realized under weather good conditions of humidity and temperature. On the other hand, the wind speed conditions are generally observed and do not exceed the 19km/h.

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The embedded system TICSAD gives the knowledge of the various sources of errors by making it possible to optimize the quality of pesticide application also to reduce the losses.

3.2. The reduction of the quantities of pesticides related to better practices

For the Life AWARE project [1], during three years, samples of water were taken with an automatic sampler to the catchments basin outlet and were analysed in laboratory. Weed-killers (58%) (Glyphosate or its metabolite the AMPA), fungicides (36%), insecticides (6%) were found with a number of weed-killers of larger concentrations. This finding is possibly explained by the fact that weed killers are directly applied to the ground and therefore are immediately found in superficial waters generated by heavy rainfalls or precipitation.

The annual quantitative variation of phytochemical products found, is very strongly correlated with quantity and intensity of rainfall, these two parameters are very variable in Mediterranean climate.

Over the three years of the project, year 2006 was characterized by one very dry spring (10mm). Consequently, there was no pressure from mildew and the adventitious ones did not develop. The wine growers thus, performed less treatment in 2006 as compared to 2007-2008. Moreover as it did not rain to a significant degree there was no transfer of pesticides towards water. The years 2007 and 2008 on the other hand exhibited important intensities of rain during spring and autumn and therefore supporting the transfer of pesticides. During those two years the wine growers had to carry out more treatments, as the parasitic pressure was stronger. These two combined mechanisms therefore explain the elevated presence, in terms of quantity and composition, of plant health products during 2007 and 2008 in Vaillèle River waters.

It appears difficult on a time span of 3 years to generate conclusions on the reduction of the quantities of pesticides related to better practices. Modelling could make it possible to test various scenarios according to the ground observations collected during the three years of the project.

For the TICSAD project the farmers were brought to evaluate the product quantity used and their way of working. In a general way, the reduction is about 10 to 15% thanks in particular to a more rigorous evaluation of the surface cultivated (exact land surveying of the surface cultivated/declared surface). In a second way, the monitoring of the dysfunction during work makes it possible to correct incidents immediately (clogged nozzles) and to avoid specific errors and localized pollution.

3.3. The use of the NICT embedded system.

3.3.1. Role of the NICT for sprayer tuning

The Embedded system sensing devices has been used at two steps by the farmer:

First, during the filling up: the tank level sensor is very useful to the farmer as it allows the farmer to stop the filling when necessary. This operation was much less comfortable when using the sprayer level indicators; point pollution is limited. In the same manner, he can do the good tune-up of flow-rate for each side of the apparatus corresponding to the Volume per hectare desired and detect dysfunctions before leaving to treat.

Secondly, during the spraying, the farmers can monitor the spraying and external parameters and therefore adapt its speed or detect any malfunction (ex: stuck nozzle); the displayed parameters are at present: the right and left flows (in l/min) and the weather parameters (then the farmer can stop if the wind is strengthening).

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Finally, thanks to the embedded system and the adjustments, the wine grower takes particular care to modify his apparatus, not only at the hydraulics but also on the spray nozzles direction and the rinsing of the tank.

3.3.2. Role of the NICT for farmer practice improvements

After data processing, useful information is presented in the form of graphs and maps, which can be used by the farmers and advisors for evaluation and improvement of farming practices. Using these types of maps, the farmer can get involved into a self-teaching scheme.

3.3.3. Role of the NICT for traceability improvement

First comparisons made with the manual traceability books show several discrepancies. These are always due to farmer errors (due to a delay in filling up the book, to writing errors…). Therefore, the AWARE & TICSAD systems offer a secure way for elaborating the obligatory “traceability field logbook”. Data are organised in order to fill it. Outputs like the one presented in Figure 9, can be automatically generated in order to help the farmer to have a guaranteed traceability.

4. PROSPECTS

On the other hand the reduction of the quantities of pesticides can be reduced by evaluating/controlling the adjustments on the sprayers and by using innovative solutions developed by the technical institutes and the research centres: programs POD MILDIUM (INRA - CEMAGREF) [5] and OPTIDOSE (IFV) [6] so that the fight against parasitic attacks can be won by using the right amount of pesticide and therefore eliminating excess applications and decreasing further contamination of water sources and environment.

To better manage these treatment methods, the TICSAD embedded system provides an obvious help. The traceability AWARE & TICSAD system could make it possible to obtain the traceability of phytochemical treatments but also to reference geographically places of infestation in the plot thanks to the integrated management of the tasks and events. A fine and objective analysis at the vine stock scale could be obtained. This approach is currently in evaluation at the Cemagref of Montpellier. The aim is also to adapt this process, developed at the plot, at the level of an exploitation that is relevant to decision making.

5. Conclusion

The NICT systems offer farmers new technology, enabling the automatic generation of reliable data, automatic feedback on current practices and real traceability on spraying and pesticide product usage. The analyse of these readings, which involves the different stakeholders, enables detection of different malfunctions and provides avenues to improve practices and equipments, thereby reducing quantities of pesticide products used and mitigating environmental contamination. It provides objective data automatically. The most important hydraulic parameters involved in sprayer functioning can be visualized and, if needed, easily corrected.

It is undeniable that the quality of application of the products is undoubtedly the first means with which the wine grower can reduce the use of pesticides. A good adjustment of the sprayer makes it possible to limit air and soil losses and drifts (they can represent from 7 to 50% according to the vegetative stage) and to avoid the over and under proportioning.

The main objective of these projects is to enable farmers to completely control the operations of their every day working tools. These tools enable the farmer to check and correct sprayer parameters on a daily basis. Geo-referenced inter-plot traceability of treatments provides an objective assessment of application quality, which allows the winegrower to analyze and

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correct operations. Thanks to the assistance provided by this tool, users pay greater attention to both hydraulic and mechanical (nozzle direction) settings, and to the general maintenance of their sprayers, with the aim of obtaining a specific result that can be immediately assessed after treatments.

NICT tools give operators the means to control pesticides application and to meet the objective of significantly reducing soil and air losses, thereby mitigating surface and groundwater pollution and atmospheric contamination. Associated with new methods of treatments like POD and OPTIDOSE, the objective to reduce the amount of pesticides used can be achieved in a short time frame, without compromising the quality of the protection necessary to achieve high yields and good quality products.

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