Reducing pesticide-related water pollution by improving crop protection practices: the use of embedded ICT technologies

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Abstract

The AWARE project shows that the optimisation of the pesticides application techniques can limit the pollution of surface water and help farmers to respect the environmental requirements of the CAP. It has 4 main actions:

1-Developing tools and a methodology to reduce the environmental impact of pesticides

- **by setting up geo-referenced data-recorders embedded on sprayers, which gives real time control of the applied pesticide and the production of an objective traceability book;**
- **by improving equipments: collective filling stations for sprayers which fulfil environmental standards, rinsing tanks and devices and sprayers adjustment;**
- **by implementing a plan of practices' improvement based on measured data**

2-Extending the results to other contexts thanks to the modeling of pesticides transfer.

3-Assessing the feasibility of knowledge transfer through implementation of the methodology in others European contexts (Spain, Italy);

4-Transferring the experience and the acquired knowledge to the european farmers and to the general public. The tests of the Aware sensing device lasted almost two years on 15 different sprayers on the Neffiès (Montpellier) river basin, showing that:

- **the system can be implemented on different type of vineyard sprayers;**
- **the devices were used for sprayer tuning and for spraying monitoring by the farmers;**
- **the device outputs can be used for generating traceability records, error free;**
- **the maps and graphs generated from the data can help improving agricultural practices and lead to the use of lower quantities of pesticides;**
- **these devices have been very well accepted by farmers**

Keywords: CAP, pesticides, health, environment, traceability.

Introduction

Context

The European Water Framework Directive sets the goal of achieving a "good status" for all of Europe's surface waters and groundwater by 2015. In France, studies carried out by the French Institute for the Environment (IFEN) show that the whole territory is concerned by water pollution. Both underground and ground water masses are affected, especially at locations where human activity is important. In 2004, the contamination levels are significant: 49% of ground water samples were graded "average to bad" quality, 27% of underground water would need to be processed for being made potable.

The Aware project, co-funded by the European Union and 9 partners in France, Spain and Italy, focuses on the impacts of agricultural activity on water resources in rural areas. It has been build up to demonstrate how the optimisation of agricultural practices and equipments related to pesticide spraying in viticulture helps the farmers to preserve the quality of water entities and to maintain a high quality of products.

The project is coordinated by the Cemagref (French agricultural and environmental research centre), and is based on a partnership between state-owned company (Conseil Général de l'Hérault (France), Chambre d'Agriculture de l'Hérault (F)), public research and training centres (Montpellier SupAgro(F), INRA(F), IRTA(Spain)) and private companies (Voe Développement(F), Ereca(F), CISA (Italy)).

Life Aware is a three years project which takes place in the Vaillèle catchment basin of the French town of Neffiès, in the south of France, where the only crop is grapevine. 15 winemakers, members of the cooperative or having their own winery, have accepted to participate actively to the project.

Environmental concerns increasingly play a role in the Common Agricultural Policy: the agri-environmental strategy of the CAP is aimed at enhancing the sustainability of agro-ecosystems. Since the Agenda 2000 CAP reform, cross compliance has been established, becoming compulsory in 2005, see C.Reg. 1782 and Comm. Reg. 796 : this is the principle that farmers should comply with environmental protection requirements as a condition for benefiting from market support. If farmers do not respect the environmental requirements, appropriate sanctions are to be applied, which may include the reduction or even the withdrawal of direct aids.

Statutory Management Requirements (in Italy "Criteri di Gestione Obbligatori" or CGO) are specific European legal requirements applicable to farmers. They comprise a number of articles from 19 EU Directives and Regulations which address the environment, public, plant and animal health, and animal welfare. In particular, there are specific CGO with regard to water protection from pollutants.

Good Agricultural and Environmental Conditions (in Italy "Buone Condizioni Agronomiche e Ambientali" or BCAA) are domestic legal requirements requiring farmers to keep their soils in good condition, and to maintain a range of habitat and landscape features which are important to the countryside. They either reinforce existing national laws or were already established good practice. As such, it is only natural that they have a very technical nature, specific to particular environments and to climate conditions: this is the reason for their definition at a regional level.

There is a specific EU regulation, see C. Dir. 414/1991 and Dir. 8/1998, finalized to minimise the detrimental environmental impact of pesticides. They have been previously regulated in most EU member states, mostly regarding their production, distribution and end-of-life stages.

Under the cross compliance regime, with regard to GAEC, the ACT B9 reminds producers and distributors of the legal requirements concerning the supply of pesticides to the market; the ACT B11 sets requirements for the use of pesticides that must be satisfied in order for farmers to get the aids from the PAC: this is linked with public health targets and mainly concerns the traceability along the food chain. Each farmer has to keep track of a series of data regarding crop treatments.

In spite of these efforts, according to official sources, as a result of misuses of pesticides, including overuses, the percentage of food and feed samples in which residues of pesticides exceed maximum regulatory limits, has not decreased over the last ten years.

Since July 2002, with the introduction of the sixth environment action programme, the European Commission adopted a document on the Thematic Strategy on the sustainable use of pesticides which is targeting specifically the use-phase of plant protection products. The Strategy addresses the threats of pesticides to human health and the environment and will ensure coherence of rules across member states. It will concern the temporary storage of pesticides at farm level, the management/calibration of application equipment, the protection

of operators, the preparation of the spraying solution and the application itself.

We think that our project, both via the new equipment and thanks to the procedures set up during our tests, anticipates some of the solutions to these problems:

- precise control of sprayed quantities, of their distribution across fields and of the metereological conditions;
- the ability to speed up the processes required by traceability, with an almost automatic production of the relative records.

It is possible that member states would consider giving a special low risk status with regard to the Integrated Administration and Control System's (IACS) procedures, to those farmers equipped with sprayers having this kind of capabilities.

Last but not least, the results from our research on modeling the catchment basin can greatly improve the understanding of the dynamic of pollutant: this in turn can lead to regional raccomandation being integrated in the existing GAEC.

Objectives

The first objective of this project is to test the capacity of information and communication technologies to help farmers reducing the total amount of pesticides released during the crop protection process. We install high quality equipments (embedded data-recorder on sprayers, a collective filling station which fulfil environmental standards, rinsing tanks on sprayers) and organize training sessions to support them in the daily use of these equipments.

The second objective is to study the relation between this decrease of pesticides quantities on a given catchment basin and the actual improvement on the water quality in the basin outlet. We try to assess the sensitivity of the water system to the variations of the total amount of molecules released.

Finally, we aim to extend the method and results to other contexts thanks to the modeling of pesticides transfer, and to assess the feasibility of knowledge transfer through implementation of the methodology and ICT recording system in others European countries (Spain, Italy).

Communication towards the wider range of stakeholders is a key issue of the project: we target farmers, advisers, research centres, students, companies involved in plant health protection, etc. We use several communication tools in order to fulfil this goal: booklets, website, reports, interactive film, and the participation to international congresses.

Materials and methods

1 Embedded data-recorder on sprayers

The Aware device aims at measuring a number of data relevant for the spraying operation and delivering them to the farmers of the Cooperative. It is made up of two parts:

- The Aware mobile device is an embedded electronic system which measures and records spraying parameters.
- The Aware Server is the processing and display unit, located at Neffiès wine cooperative.

Aware mobile consists of embedded electronics on the tractor (MPU) and on the sprayers (APU). Data recorded by the Aware Mobile are the following:

- meteorological data: temperature, humidity, wind direction and speed
- tank level
- right and left flows of the sprays,
- Geographical position and tractor speed by GPS sensor.

Figure 1

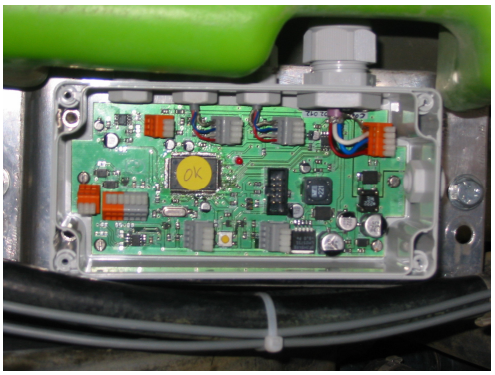

Figure 2

The MPU (Fig. 1) manages the GPS referencing, the climate data, the data display and man-machine interface (for manual data input), so as the WiFi interface to data transfer. The APU (Fig.2) deals with acquisition of data related to tank level and right / left flows.

The Aware Server unit is aimed at:

- recording and processing the data of each tractor in order to compute trajectories and to merge data;
- generating information related to the sprayed plots and to the various processing dates.

A Geographical Information System (GIS) has been implemented for gathering and process all terrain data (tractors trajectories, topography, hydrography, vineyard plots etc).

The sensors have been implemented on the sprayers of 15 vineyard growers, representing 80% of the vineyard plots of the river basin. These sprayers were all of different brands and models and the setting up has been realized without any major problem (Fig 3).

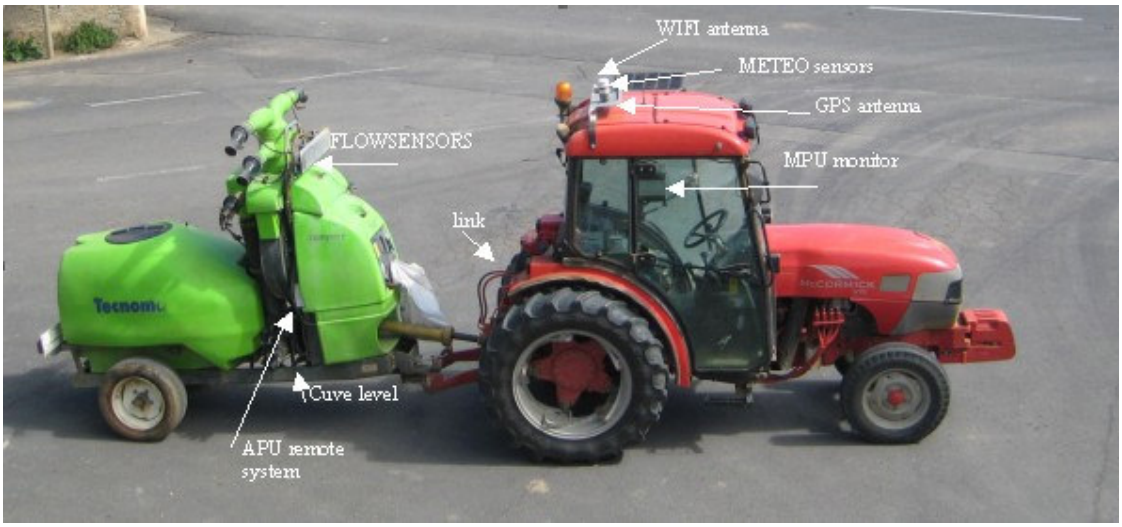

Figure 3

Both the Mobile and the Server Aware units have been developed in order to be as user-friendly as possible: the Aware project also deals with assessing the acceptation of the device by vineyard growers. Two training sessions have been organized, one in July 2006 and the other one in October 2006, in order to carry out a first return on experience from the farmers.

One campaign was carried out in 2007 with these 15 sensing devices. At the beginning of the season all sprayers have been cleaned and tuned. Various parameters are checked

during the training sessions: the nozzle orientation, the cleaning up and the maintenance of the sprayer between two spraying operations; the tuning of the right and left flows.

In parallel to the spraying data recorded by the Aware device, the farmers are invited to fill up a "spraying book", in which all data dealing with spraying are theoretically written.

2 The catchment basin approach - impacts on water

2a Equipments

Several equipments were installed to study the catchment basin system. At the outlet of the basin, across the river, a crest has been fit out with measuring and sampling devices so that

- the river flow is measured and recorded at different time steps.
- water samples are automatically taken during floods

The water samples are analysed by an independent laboratory which looks for the presence of a wide range of pesticides (fungicides, acaricides, insecticides, weed control molecules). A weather station in the middle of the catchment basin records the climate parameters every 10 minutes, such as rain intensity and wind speed. The former measure is a key data for analysing the hydrological response of the basin to heavy rainfalls. The later helps the farmers to decide whether to spray or not, depending on the wind speed.

2b Modeling the hydrological system

One of the goals of the project is to evaluate the relation between the amount of pesticides released in the plots and the concentration of molecules found in the river at the outlet of the catchment basin as in Voltz (2003). Since the Aware project lasts only 3 years, and considering the significant climate variability in the south Mediterranean context, we chose to use modeling tools to study the way rainfalls and agricultural practices influence the level of the water pollution: the modeling is based on the deposits over crops and ground and on the rainfalls. The partner Lisah has been developing the hydrological model Mhydas on another close catchment basin (Roujan) for 15 years. This model was then calibrated on our experimental site in Neffiès. The whole area has been parted into homogeneous hydrological zones (at ground and underground level). We can apply a rainfall quantity and pesticides quantities on each plot and let the model calculate the river flow and the concentration of pesticides molecules in the river (or everywhere else in the area). Basically, we use Mhydas to test different scenarios of agricultural practices in various climate conditions. We focus our work on the following aspects of the river pollution:

- The impact of the geographical position of each plot considering the distance to the river
- The role of a controlled grass between the vineyard rows
- The impact of the time between the pesticide application and the following rainfall
- The sensibility with regard to the amount of pesticides sprayed

We can use this tool to show stakeholders what progress are made depending on the climate, the organization of vineyards, the pesticides used by farmers, the quantities involved.

Results

1 Agricultural practices

1a The role of the Aware devices for sprayer tuning

The Aware sensing devices were used at two stages by farmers, in an on-line configuration:

First, during the filling up: the tank level sensor is very useful to the farmer as it allows him to stop the filling when necessary. This operation was much less comfortable when using

the sprayer embedded level sensors and the Aware sensor is more accurate. The farmer can precisely adjust the water volume needed for the set of plots he planned to work on.

Second, during the spraying, when the farmer can monitor the spraying and external parameters and therefore adapt his speed or detect any dysfunction (ex: stuck nozzle…). The displayed parameters are: the right and left flows (in l/min.), the tank level and the weather parameters (the farmer can stop if the wind is strengthening or above the allowed threshold).

1b The role of Aware devices for farmer practice improvements

All the data recorded during spraying operations are processed and organized in an easy and readable format. They are turned into graphs and maps, which can be used by farmers and advisers as a base for training sessions or self-improvement.

For instance, a graph can show a lack of balance between left and right sprayer arms. The regular flow drops can indicate that the farmer systematically switch off the flow when arriving at the plot border. We can graph the wind force, and check if the application has been done under the upper authorized speed, i.e. 19 km/h (in France).

Maps are also very informative for farmers and they can get involved into a self-teaching scheme. We can map the total flow (addition of right and left flows) sprayed on a plot, clearly showing such things as:

- the farmer switching off at the border of the plot between each row;
- overlapping that caused some over-dosing.

1c The role of Aware devices for traceability improvement

Data can also be organised in order to fill up automatically a "traceability book", similar to the one that is filled compulsorily by the farmer but with objective information : see Fig. 4.

First comparisons made with the manual traceability books show several discrepancies, often due to farmer errors (caused by a delay in filling up the book, by writing errors…).

	Traçabilité automatique	Traçabilité papier	Comparaison
Date du traitement:	2007-06-25	2007-06-19	Dif
Parcelle traitée	**13B** (surface déclarée=0.85Ha, interrang=2.25m,intercep=1.0m)		
Produits utilisés			
Produit 1:	**None : None**	**sirbel** (2000160) à **1.3** l/ha	
Produit 2:	**None : None**	**collis** (2060085) à **0.4** l/ha	
Produit 3:	**None : None**	() à	
Produit 4:	**None : None**	() à	
Produit 5:	**None : None**	() à	
Produit 6:	**None : None**	() à	
Caractéristiques du traitement			
Vitesse de fonctionnement	**4.7** km/h	4.6 km/h,	2.17 %
Débit gauche de fonctionnement	**2.93** L/min	différence gauche-droite: -0.1	
Débit droit de fonctionnement	**3.03** L/min		
Débit total de fonctionnement	**5.97** L/min	**5.87**	1.7 %
Passe tous les :	**1.8** rangs	2 rangs	-10.0 %
Volume de bouillie pulvérisé	**152.52** L	-	
Surface traitée	**0.93 / 0.97 Ha**	-	
Volume de bouillie par hectare	164.0 L/ha	170.0 l/ha,	-3.53 %
Conditions météorologiques			
Force du vent moyen	5.0 km/h (1.4)	2 - legere brise	dif=-0.6
Force du vent maximum	**11.8** km/h (2.5)	-	
Température moyenne	**19.0** °C	-	
Température maximum	**20.2** °C	-	
Humidité moyenne	**59.0** %	-	
Humidité minimum	**54.0** %	-	

Figure 4

2 Impacts on water quality

2a Understanding of the catchment basin hydrological behaviour

The data from the devices installed in the outlet and in the weather station shows that the catchment basin rapidly responds to heavy waterfalls; as in many Mediterranean basin rainfalls are rare and heavy, mostly concentrated in spring and autumn.

The time between the flood and the return to the initial water level is due to a water table situated at the top of the catchment basin. This explains also why we constantly have water in the river, even during very dry periods in summer.

The analysis of the samples of water taken in the outlet reveal the presence of several molecules, mainly fungicides and herbicides (diuron, glyphosate, aminotriazol, terbuthylazin desethyl). We studied the trend of the concentration of one molecule found in every water sample from the beginning of the project. It comes from the terbuthylazin, an herbicide which is not used in France since 2004 in vineyards. Our result is related to the pesticides life cycle: the molecules are stocked in the soils during their use and progressively released and transported by the combined action of the physical and chemical processes. This example emphasizes the fact that a long-term survey must be done on each catchment basin to follow the evolution of the concentrations year after year.

Since Aware lasts only 3 years, we use the modeling tool Mhydas to study the evolution of the pollution by pesticides molecules in a middle and long-term approach.

2b First results on modeling the catchment basin

The whole study will be completed during the year 2008. The first results come from the sensitivity modelling done on Mhydas for the following types of model inputs. We observe how one variation of each model input influence the outputs of Mhydas (river flow rate, concentrations of molecules, volume flowed, mass of molecules)

- Meteorological parameters: the main processes to take into account are the rainfall intensity and the soil water content before the rainfall.
- Cultural parameters: the initial state of the soil surface is a key parameter. It is conditioned by the practice of the farmer about weed control. In case of ploughing, the soil surface will be modified and the transport of pesticides decreases. On the contrary the use of herbicides does not change the soil properties. The other important parameters are the amount of pesticides sprayed on the plot, and the delay between the spraying and the following rainfall.
- Physicochemical characteristic of each pesticide are not very sensitive compared to the previous one.

Conclusions

Lowering the pollution of the water masses by pesticides is a challenge for the farmers. In order to lead pertinent studies on catchments basin, and to propose to farmers several way of amelioration, scientists and agricultural advisers need to develop tools to measure the real quantities of chemical released in the environment and to deduce the risk of pollution for the close rivers and ground waters.

The Aware project combines the recording of objective traceability data by embedded systems, the numerical modeling of pesticides pollution (Mhydas) and the training offered to the farmers based on the results.

The originality of the Aware project lays on all the data collected automatically from the wine growers' sprayers. We can lean upon objective and accurate data, and we gain a great comprehension of the farmers' behaviour by comparing what they thought to be doing

and what was eventually done.The first results on modeling the catchment basin help to prioritize the different parameters involved in pesticide transfer on a given area with a given climate. We then can choose which practices must be changed first, and what is the breathing space.

The Aware sensing device has been tested during almost two years on 15 different sprayers on the Neffiès river basin. This experiment has shown that:

- these systems can be easily implemented on different type of vineyard sprayers;
- during operations the devices were used by farmers for sprayer tuning, and for spraying and filling up monitoring
- the device outputs is used for generating automatic traceability books;
- the maps and graphs generated from the sensor can be used by advisers for training farmers, in order to improve agricultural practices. In most cases, lower quantities of pesticides can be used thanks to the better knowledge of the sprayers' behaviour.
- these devices had been very well accepted by the farmers

The next stage is to assess the feasibility of transferring the methods and results in other contexts, and in other countries which are partners of the Aware project, i.e. Spain and Italy.

At the end of the project, we will write a "book of good practices" in order to help the stakeholder to combine a high quality production level and the lowest impact possible on the environment.

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