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

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ICT: Information and Communication Technologies

Abstract

The project AWARE aims to show how the optimisation of the pesticides application techniques can limit the pollution of surface water. It takes place in the small catchment basin of Neffiès (a village in the south of France, 80km far from Montpellier) and focuses on vineyards.

The project lasts 3 years (from 2006 to 2008) and is articulated on 4 main actions:

* Developing tools and a methodology for reducing the pesticide amount introduced in the environment:

- By setting up geo-referenced data-recorders embedded on sprayers, which allow mastering of the pesticide volume applied in real time and the production of a objective traceability book for the farmers;
- By improving equipments (collective filling stations for sprayers which fulfil environmental standards, rinsing tanks and devices and sprayers adjustment);
- By designing and implementing a plan of improvement of practices based on the records and their analysis.

* Extending the results in time and to other contexts thanks to the modeling of pesticides transfer. This modeling is based on the following inputs: deposits on crops and ground of plant health products and rainfalls;

* Assessing the feasibility of knowledge transfer through implementation of the methodology and ICT recording system in others European contexts (Spain, Italy);

* Communicating and transferring the experience and knowledge towards the stakeholders and mass audience.

After 2 years of project, all the tools installed to help the farmers during plant health protection processes have been well accepted. They now have the capability to work with the lowest impact possible on the environment. The comparison between the “paper” traceability and what is calculated from the sensors data is a very interesting base of arguing during the training sessions (what is the breathing space). 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. Next step will to confront many different scenarios of practices on different climate conditions and different contexts.

I.Introduction

1. 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 all the territory is concerned by water pollution. Both underground and ground water masses are affected, especially at locations where human activity is important (agriculture, cities). 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 help the farmers to preserve the quality of water entities and to maintain a high quality production.

It 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 south of France, where the only crop is grapevine. 15 winemakers, members of the cooperative or having their own winery, has accepted to participate actively to the project.

2. 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 contexts (Spain, Italy).

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

II.Actions and means involved

1. Embedded data-recorder on sprayers

One of the key actions of the project is to introduce high-tech tool on the farmers tractors and sprayers, to assess their acceptability and to figure out how they help people to better use their machine. 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 measure and record spraying parameters.
- The Aware Server is the processing and display unit, located at Neffiès wine cooperative;

Aware mobile consists in 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.

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 fuse data;
- generating information related to the sprayed plots and to the various processing dates.

Fig 1: The MPU unit in the tractor cabin

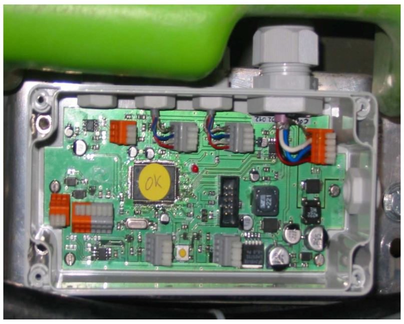


Fig 2: the APU box on the sprayer.

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

The sensors have been implemented on the sprayers of 15 vineyard growers, representing 80% of the vineyard plots of the Neffiès river basin. These sprayers were all of different brands and models and the implementation has been realized without any major problem (Fig 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. In 2006, two training sessions have been organized, one in July 2006 and the other one in October 2006, after the agricultural season, in order to carry out a first return on experience from the farmers.

One campaign has been 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.

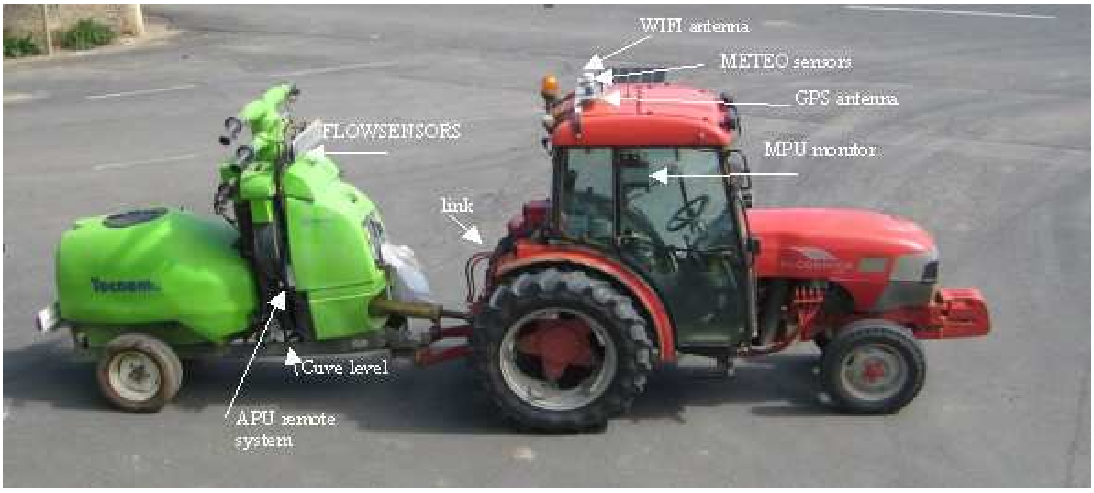


Fig 3: the implementation of the Aware device on the Cemagref tractor.

2. The catchment basin approach - impacts on water

a. Equipments

Several equipments have been installed in order 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 (Fig 4) so that

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

Fig 4: a/crest before rehabilitation b/Equipments at the river crest: water sampler and flow recorder

The water samples are analysed by an independent laboratory which look 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 to spray or not, depending on the wind velocity.

b.Modeling the hydrological system

One of the goal 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. 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 partner Lisah has developed the hydrological model Mhydas on another close catchment basin (Roujan) for 15 years. This model has been 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 of water fallen down the catchment basin) 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).

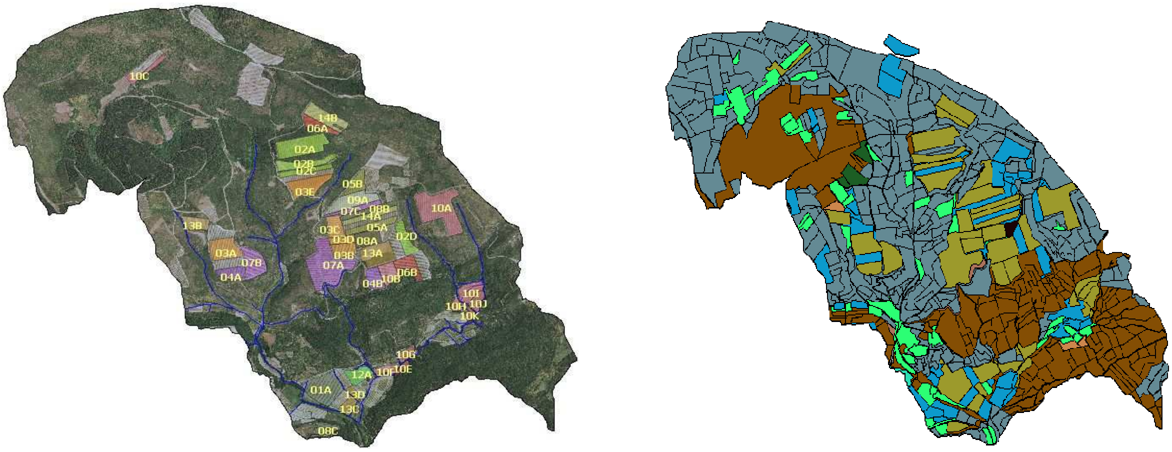


Fig 5: a) View of the catchment basin with the studied plots b/Segmentation of the catchment basin for Mhydas

Basically, we use Mhydas to test different scenarios of agricultural practices in various climate conditions. We focus our work on the sensible impacts on 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 impact of a lower amount of pesticides sprayed by each wine-grower, or by only a number of them

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

III.Results

1. Agricultural practices:

a.Role of the Aware devices for sprayer tuning

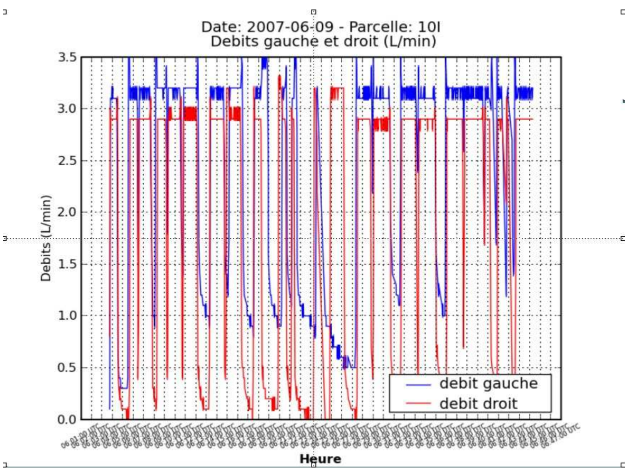
The Aware sensing devices have been used at two steps by the farmer, in an on-line configuration:

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

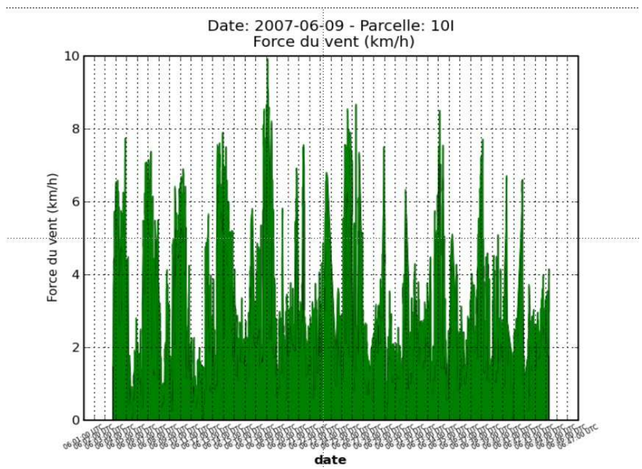
b.Role of Aware devices for farmer practice improvements

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

For instance, the graph from figure 6a shows a lack of balance between left and right sprayer arms. The regular flow drops show that the farmer systematically switch off the flow when arriving at the plot border. Fig.6b shows that the wind force, although unstable (varying between 2 and 10 km/h), never goes above the upper authorized speed, I.e. 19 km/h (in France).



a:



b :

Fig 6. Graphs recorded by the Aware device: a) the right and left flows, b) the wind speed.

Maps are also very informative for farmers. On Fig.7 is shown the map of the total flow (addition of right and left flows) sprayed on a plot (almost one hour of spraying)

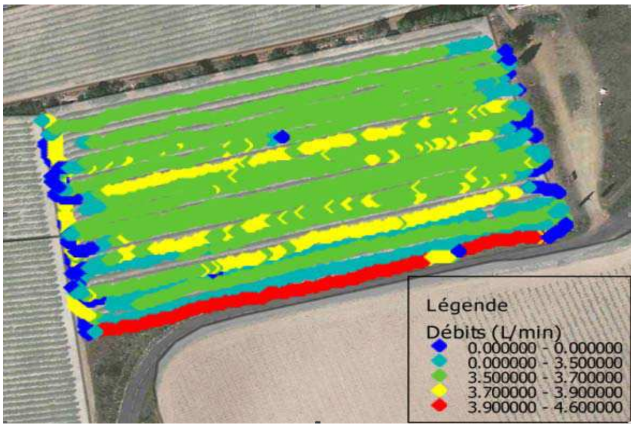


Fig. 7: Map of total sprayed flows on a plot.

This map clearly shows that:

- the farmer switches off at the border of the plot between each row;
- there are some overlapping and therefore some over-dosing (in red) in the plot;

Using these types of maps, the farmer can get involved into a self-teaching scheme.

c.Role of Aware devices for traceability improvement

Data can also be organised in order to fill up a "traceability book", similar to the one that is filled compulsorily by the farmer. Outputs as the following (Fig 8) can be automatically generated in order to help the farmer to have a guaranteed "traceability book" (objective data).

	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** %	-	

Fig. 8. An example of one sheet of the « traceability book » automatically generated by the Aware devices.

First comparisons made with the manual traceability books show several discrepancies which are often due to farmer errors (due to a delay in filling up the book, to writing errors…). Therefore, Aware offers a secure way for elaborating the “traceability book”.

d.Conclusion

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

- these systems could be implemented with no major problems on different type of vineyard sprayers;
- during spraying (including filling up), the devices were used for sprayer tuning and for spraying monitoring by the farmers;
- the device outputs could be used for generating traceability books with a higher fidelity than the one of manual traceability;
- the maps and graphs generated from the sensor could be used by the advisors 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

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2. Impacts on water quality

a.Comprehension of the catchment basin hydrological behaviour

The data from the devices installed in the outlet and the weather station shows that the catchment basin rapidly responds to heavy waterfalls, as many Mediterranean basin (Fig.9) Rainfalls are rare and heavy, mostly concentrated in spring and autumn.

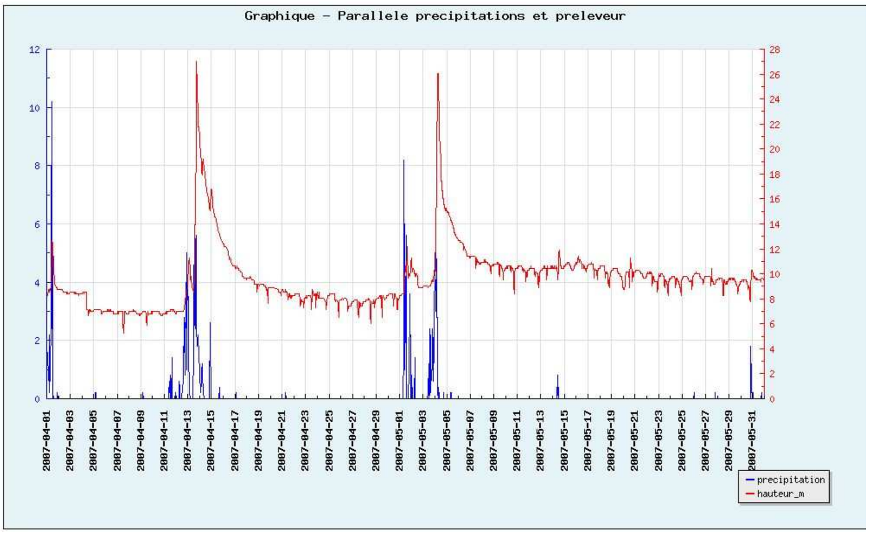

Fig 9 – River level (red curve) response to rainfalls (blue curve)

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). Fig. 10 shows an example of the evolution of terbuthylazin desethyl.

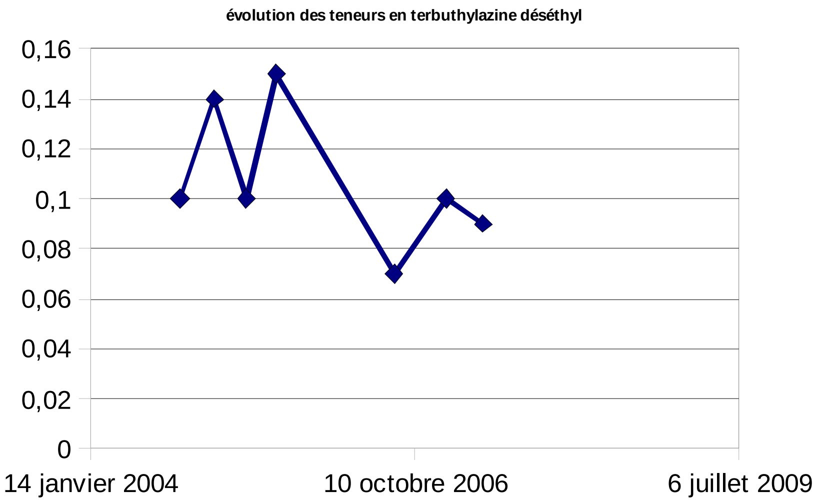

Fig. 10 – Evolution of the concentration of terbuthylazin desethyl (ųg/L) during the project

This graph shows 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. This 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 help of the modeling tool Mhydas to study the evolution of the pollution by pesticides molecules in a middle and long-term approach.

b. First results on modeling the catchment basin

The complete study will be completed during the year 2008. The first results come from the sensitivity study 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 surface soil 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 so that the transport of pesticides decreases. Contrary to the use of herbicides which 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.

IV.Conclusion

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 them several way of amelioration, scientists and farmer advisors 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 brought 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 do and what is really 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. This way we can choose which practices must be changed first, and what is the breathing space.

Next technical step 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 a good practices" in order to help the stakeholder to combine a high quality production level and the lowest impact possible on the environment.