# VIGICULTURES – An early warning system for crop pest management

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## Abstract

In 2008 and 2009 the main French Agricultural Institutes developed and used a Management Information System. This system was aimed at collecting, processing, storing and disseminating observational data on the main crop pests (on cereals, maize, pulses, potatoes, oilseeds, sugar beet, flax) in real time. These up-to-date measurements of crop pest and disease activity are collected by technicians or trained farmers.

This paper outlines the Vigicultures® structure and provides concepts behind the different modules. It also demonstrates the Information and Communication Technologies utility for crop management and more specifically in early warning systems for pest control.

The Information System we developed is a web portal that allows users to collect, share and consult real-time data. Agronomists can consult formatted data to support their decisions on their regional pest and disease control. An API Google map mashup presents dynamic maps of the French regions where data were collected. This combines dynamic color icons and charts allowing data mining and facilitating interpretation (disease or pest infection level). In addition, to accelerate data collection, we added mobile web pages using the latest mobile technologies (XHTML) for field data transmission by smartphone.

Finally, one of the most interesting characteristics of this web portal is its structure. It communicates with a variety of information systems and databases. Each institute stores data in its own databases and feeds the web portal with XML web services. Aggregation, processing and viewing are possible by message standard transmissions elaborated between the four institutional partners.

The use of Vigicultures® for territorial surveillance and pest control during the last two seasons allowed producers to reduce their risk of losses. It is a success, judging by the number of users. But we can improve the system and give it more value. Assessment, calibration and dissemination of epidemiological models are in progress and can strengthen the system's usefulness.

## 1. Introduction

The plant protection service of the French Ministry of Agriculture has for many years been responsible for publishing *Agricultural Warnings*®, which monitored the pests and diseases throughout the country to inform farmers and to supervise and reduce the use of pesticides. The scientific basis of the warnings rested largely on ecological considerations, because they were a schematic application of knowledge of the relations existing between the evolution of pests (which will be taken here to include diseases) and that of the plant host as a function of the weather (Grison, 1992). Biological and meteorological networks were therefore established from the beginning of the 20th century until the 1990s, and these provided most of the contributions to the warnings before being supplemented by modeling (Rouzet et *al*. 2003). The advent of models and the growing use of automated weather recording stations in the preparation of the warning bulletins however has never replaced the observational networks, a plant hygiene situation being a synthesis for which field observations are essential (Rouzet et *al.* 2006). The State services, which were the precursors of the modeling aspects of pests, have however never made use of the web to collect and summarize observational data and to model, facilitating the preparation of the warnings.

When, in 2007, the State announced that it was going to progressively overhaul its *Agricultural Warnings*® service by bringing in the various stakeholders from French agriculture, the arable crop technical institutes joined in. The aim was to reinforce the pest surveillance networks as part of the *Ecophyto 2018* government plan. The achievement of such a scheme required the organization of networks mobilizing all the partners (trade, agricultural development etc.) with a sufficient coverage of the country and the collection of reliable and organized data in an open information system to manage the phytosanitary risks and for early detection of emerging risks (DGAL, 2009).

The technical institutes ARVALIS – Institut du végétal, CETIOM, ITB and ITL joined together and offered their capacity to federate networks at the local level, their expertise in observation methodology (by training observers) and in risk analysis. Using the existing model for growing sugar beet, developed by ITB (ITB, 2008), they created a new simple, quick, effective information system: Vigicultures® (Simonneau et *al*. 2009). This has now been adopted in 17 of the 21 regions to assure the recovery of information as part of the new *Bulletin de Santé du Végétal* (Plant Health Bulletin).

In collaboration with local partners (Chambers of Agriculture, State services, storage firms, farmers etc.) they have encouraged a new organization for the biological surveillance of France based on observations and up-to-date scientific and technical data for use in regional bulletins.

These bulletins describe the health of the crops (diseases, pests and other disorders) and the level of risk for a given region. There are no recommendations for treatment and they are written by people whose job is independent of the sale of pesticides.

In this article we will quickly present some international work similar to ours, followed by an overview of the whole Vigicultures ® information system, by illustrating the most interesting aspects and an assessment of its use.

## 2. Related work

We do not intend here to present an exhaustive inventory of the existing tools for the biological surveillance of territories ; just a few internationally well-known tools for dealing with problems like ours.

In the United States, the *National Agricultural Statistics Service* publishes in its site ***Crop Progress*** (USDA, 2010), a weekly bulletin on the state of crops by State. The bulletins show the week's weather and possible crop damage in terms of yield loss. The physiological state of crops is also assessed, together with monitoring of harvests and sowings.

As to disease monitoring, another project coordinated by the USDA has enabled an information system of field monitoring to be set up. The **PIPE** project (*Pest Information Platform for Extension and Education*) has enabled soybean growers to reduce fungicide applications, which has had a very positive economic and ecological impact and thus has demonstrated the value of a national system of pest control (Isard et *al*, 2006). It is based on an observation network, diagnostic laboratories, management of databases, modeling, agronomic interpretation and the regular diffusion of information on an IT system. A web portal allows transfer of field observation data to a national database. Researchers then add value to the observations by modeling and risk analysis. Finally the portal allows the user to visualize these syntheses on a map of the United State of America.

**Crop Monitor** (HGCA, 2010) is a service putting on-line regular updated reports of crop diseases in England. It is also based on observation data collected on several sites scattered over the country. It provides information on decision aid tools for plant diseases and risk prediction.

Finally the **pl@nteInfo** project (Thysen, 2007) which has been in place since 1996 in Denmark, brings together Danish farmers and advisors around a website which provides information on weather, crop observations, decision models and varieties.

## 3. Vigicultures® : presentation of the Information System

The primary objectives of Vigicultures® were to make available to regional players responsible for biological territorial surveillance a rapid, flexible and adaptable information system able to manage information so as to fit the needs of field observers whilst being simple to use and reliable.

The tool also had to be adaptable to cope with new data, and very open, to encourage the exchange of data between the different stakeholders involved.

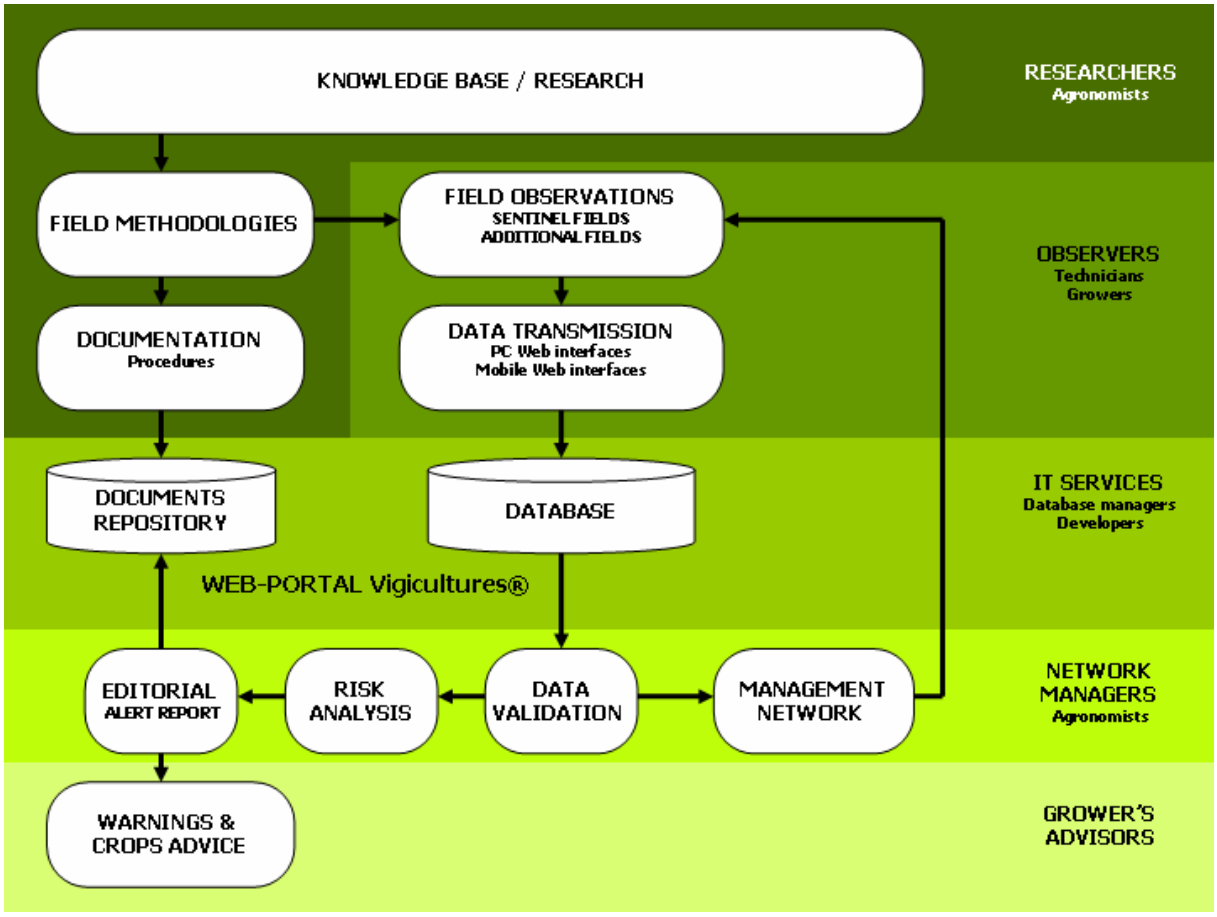


Fig. 1. The information flow in Vigicultures®

### Presentation of the information system

Agronomic and crop protection knowledge are the foundation stone of the system (figure 1). They have enabled a specialized observation methodology to be developed for each pest and crop. They are based on the knowledge of researchers in every institute and have mostly been published, as for example for wheat diseases (ARVALIS, 2007). These methodologies are applied by the observers, grouped into regional networks, to a number of fields chosen at the beginning of the growing season. These « sentinel » fields are monitored regularly by observers who upload the data observed on each pest into the information system. Depending on the situation, these networks of selected fields are complemented by information measured on additional fields to alert the network managers to a particular risk situation.

Data are collected weekly but possibly more often, depending on the pests. All the data collected are immediately available to all the stakeholders in the network. The information is thus generated and disseminated in real time. The network managers check and synthesize the information, sometimes with the help of models. A weekly bulletin is then written and published over the network. This freely distributed bulletin may then be offered in other forms by agricultural field advisors to advise farmers whether or not to apply treatments.

## The database

One of the novel features of the information system is that it is based on a network of databases administered by each technical institute. This variable architecture is not visible to the user, who accesses all the databases in a uniform way via a single web portal. Thus each technical institute, which manages its own crops, remains the owner of its data, and only stores in its database the data with which it is concerned.

The collection and posting of data on the web portal is done by *XML web-services*. This allows observers who have to manage several crops to connect just once to a single tool to transfer and consult all their observations. The portal was developed in this way so that the data to be collected and published could be managed dynamically. A crop reference system can in this way be modified by one of the partner institutes without us having to change the structure of the information system.

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## Web interfaces

We developed the web interfaces in php and most of the content is based on a Postgres SQL database. Ajax functionalities were added to increase the flow and improve the ease of navigation. Access to the http://www.vigicultures.fr. site is restricted by login and password. A user must be authorized to access the list of his fields and to add to or consult observations.

Once the user has been authorized and his rights have been assigned by the administrator, he is entirely free to create/modify/delete his « sentinel » fields. He creates them by keying in a certain number of characteristics (species, soil type, sowing date etc.) to facilitate the interpretation of the observations which are to be collected later. All the fields must be geo-referenced so that the results can be used for cartography. Once all his fields are recorded in the database, the user can access it via the web portal or the mobile interfaces at any time to add to or modify the observations.

The observations are measurements of the levels of infestation/infection of the crops by pests, and the data required are standardized and conform to the observational methodology described in the procedures published on the portal. Some may need specific field equipment. The European Corn borer (*Ostrinia nubilalis*) for example requires the use of light or pheromone traps (Doucet et *al*, 2009). To anticipate the risk from Sclerotinia (*Sclerotiniaceae*) of oilseed rape, CETIOM provides observers with a kit to determine the number of infected flower petals (Penaud et *al*, 2009).

Once connected to the web portal, each observer then knows which data he must update, depending on the crop and the observation period.

The value to the users is all about the sharing of information. Thus, the Vigicultures® portal allows every user to see in real time the data keyed in by all the partners in the network, whichever organization they belong to. Since every item of data is immediately visible and identified by its source, there is a spirit of competition which encourages contribution (missing data are also identified) and an initial checking which assures good quality results.

The network managers play a role in leadership, in a final check of the quality of the data, and as experts in writing the bulletin. They have access, just like every observer, to the chronological tables of data summaries and the methods for extracting data, which allow them to validate and interpret the results. The web interfaces of the tool facilitate the analysis by identifying in color data exceeding the thresholds for each pest (figure 2).

Dynamic graphs also make it possible to follow, field by field, changes in the incidence of pests. The kinetics of change of certain pests are moreover often essential for analyzing the risk.

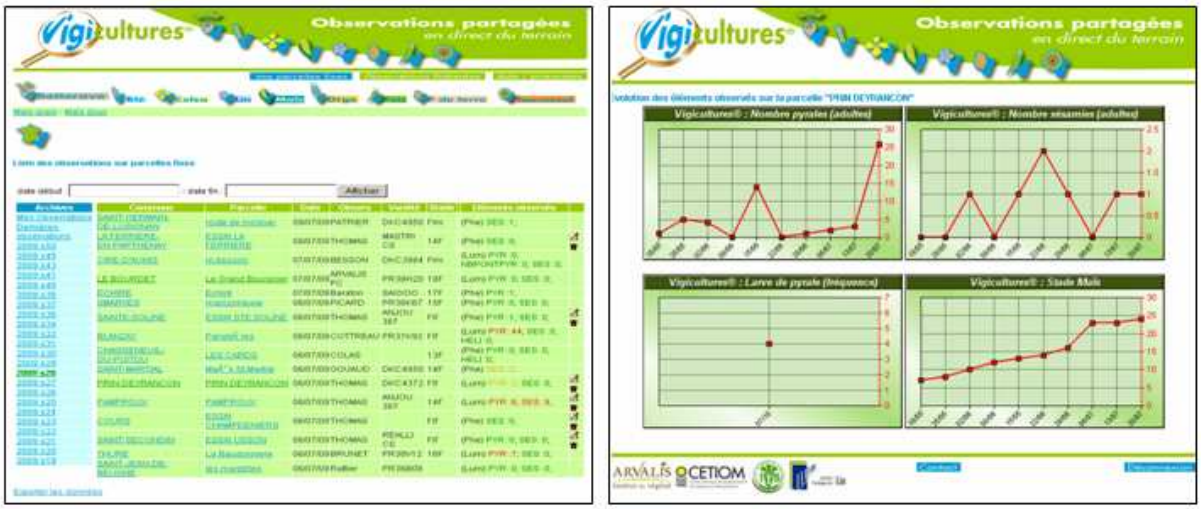


Fig. 2. Web interfaces for users of Vigicultures®

## Mobile interfaces

In view of the need for an extremely responsive system, allowing bulletins to be written very quickly with the latest data, it was considered necessary to provide observers with a way of inputting data in the field. We therefore considered developing interfaces for the Pocket PC, but this choice was quickly dismissed because of the major drawbacks with this technology (Gavalas & Economou, 2007). The need to install an application on different manufacturers' systems was too risky in terms of compatibility problems and the likelihood of increasing calls for assistance. The problems of connection in real time were not resolved (the necessity for synchronizing data on the web). Lastly, the IT developments would have necessitated the use of technology other than that used for the web interface.

The recent arrival of mobile phones with Internet browsers, although restricted in terms of screen size and display speed, has opened up a new communication support widely used by users. Today nearly everybody in France has a mobile phone with this facility and the G3 and GPRS data networks are widespread and offer sufficient coverage to send a few data observations from anywhere.

We therefore developed XHTML web pages allowing a user to access his list of fields from a mobile, and to add a series of observations simply from a drop-down menu. As the operation of transferring data does not take more than a minute per field, this capability has allowed some observers to send data to the network directly from the fields just before the publication of the bulletin.

## Geographical display tools

The visual exploration of data for this type of tool necessitates a spatial representation of the information. The interpretation of the observational data from the network on the scale of the administrative region can be convivial, rewarding and highly interactive.

Given the constraints and the public and free nature of the data disseminated, API GOOGLE MAPS was a good choice for disseminating the Vigicultures® data.

We therefore developed a composite cartographic application to display, for each crop, pest and observation period, regional maps of damage representing the network of observation fields by colored spots according to the recorded scores (figure 3).

The novelty of the system is that it allows one to explore the map dynamically and to click on fields to read in a bubble information tracing the data (the name and organization of the observer, date and result of the observation) and to have access to a dynamic graph of the evolution of the damage on a field.

Hence it is more a tool for displaying and exploring the data, useful for interpretation, than a simple tool for editing and printing maps.

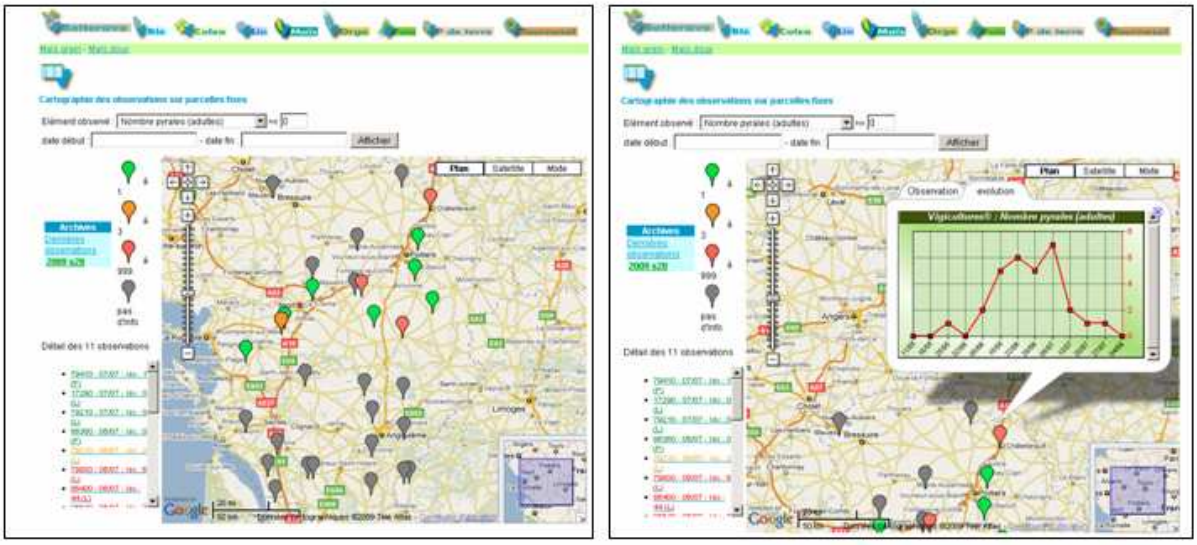

Fig. 3. Interactive map of the regional network of Vigicultures®

## 4. An appraisal of the use of Vigicultures®

The web portal was rolled out in 2008 after several months of development and testing. It was very rapidly disseminated over several regional networks and has opened up progressively to an expanding list of crops and pests (Table I).

Table 1. Statistics of Vigicultures® use for the years 2008 and 2009 (cumulative numbers)

| Crops | fields | observers | observations |
|---|---|---|---|
| Sugar beet | 220 | 88 | 5 539 |
| Durum wheat (winter and spring) | 179 | 88 | 3 035 |
| Wheat (winter and spring) | 1 910 | 839 | 74 018 |
| Rapeseed | 1 587 | 921 | 54 831 |
| Flax Fiber (winter and spring) | 64 | 44 | 2 802 |
| Flax seed (winter and spring) | 5 | 4 | 139 |
| Sweetcorn | 33 | 7 | 373 |
| Maize grain | 2 530 | 289 | 18 175 |
| Barley (winter and spring) | 486 | 341 | 8 985 |
| Pea protein (Winter and Spring) | 61 | 48 | 1 724 |
| Potatoes | 32 | 17 | 395 |
| Sunflower | 83 | 53 | 2 308 |
| Total | 7 190 | | 172 324 |

The network of sentinel fields is spread over the whole of France (figure 4) and the density of fields per crop is a reflection of the main production areas.

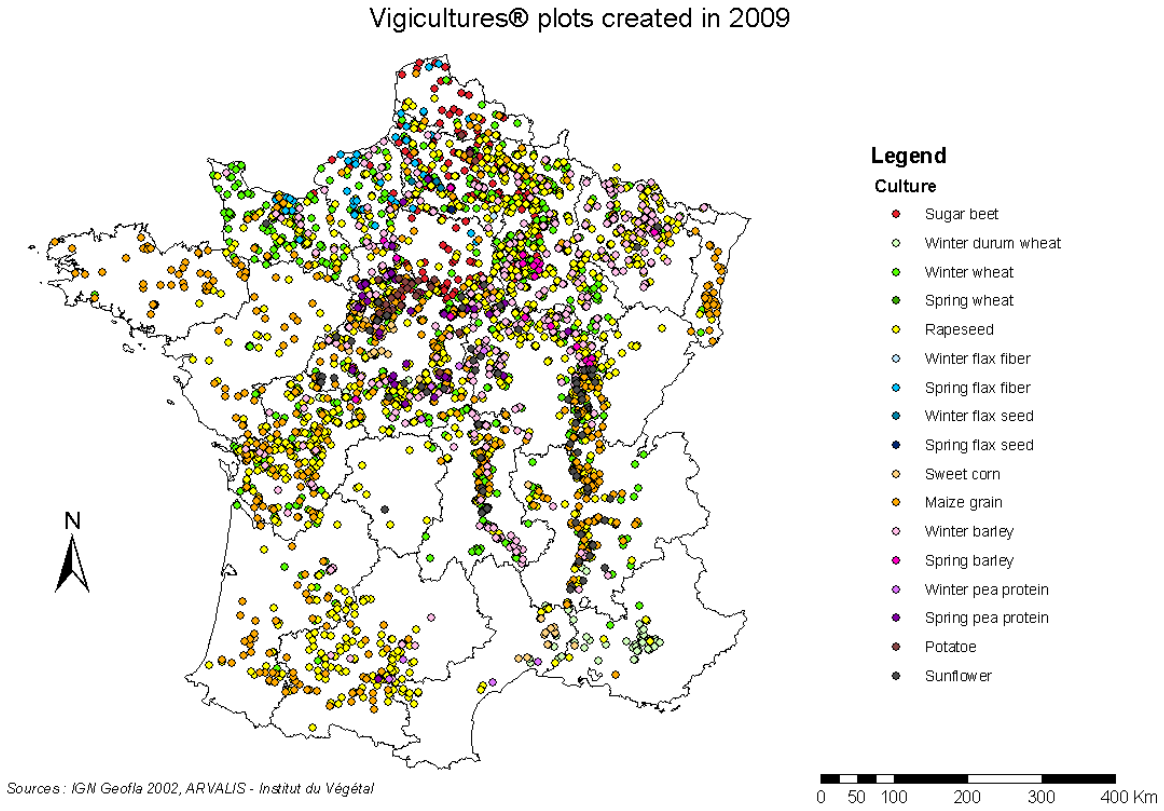


Fig. 4. Fields of the Vigicultures® network in France : 2009

## 5. Conclusions and Prospects

The growing number of users of Vigicultures® in the last two years demonstrates the value of the information system as part of the French biological surveillance system. Although it is already a success, user feedback tells us that various improvements are needed:

- the management of user rights must be improved, especially to allow the network managers to remove or mask data for suspect observations. This management could be coupled with an automatic e-mail alert to inform users when a new bulletin is published or to inform them that their data has been removed.
- a *back-office* will be developed to allow the network managers to upload their bulletins or other documents to share with their partners without the assistance of IT support.
- a more advanced request tool (Business Intelligence) will be developed for the network managers to allow them to exploit their data more thoroughly.
- a new web-mapping tool based on *MapServer* technology, offering the advanced functionality of a GIS, such as execution of spatial requests and exporting .pdf maps, will be introduced during 2010. It should offer the possibility of superimposing different layers, combining observed and modeled data.
- usage of the site is such that it has become a critical system, meaning that if it were to go down for a long time the consequences could be serious. In the case of prolonged unavailability of the portal, no bulletin could be issued. We need therefore to put in place solutions guaranteeing the availability of the portal.

Concomitantly with this IT work, other scientific and technical work will continue :
- A statistical study in progress aims notably to assist the structuring of the observation networks. Mainly it aims to determine *a priori* the number of fields (*n*) to observe in a given region, pest and week. It is based on knowledge of the variability of the phenomena studied, the mean levels expected (the technical institutes have several years of observational data) and the desired precision.
- Another study about to begin aims to improve the precision of the models. In fact the web portal, the sentinel plots, and the observer network set up for Vigicultures® provide an opportunity to have a huge amount of real-time field data which could improve our models by means of statistical calibration methods.

Finally, concerning the longer term prospects, assuming the introduction of an official national database managing all crops (tree crops, vines, vegetables, etc.) maintained by the State services, it will be necessary to set up a rapid, secure system of communication to transfer the arable crop data contained in Vigicultures® into this database.

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