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EIS Pesticides: An environmental information system to characterize agricultural activities and calculate agro-environmental indicators at embedded watershed scales

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ABSTRACT

The French "Ecophyto 2018" program calls for a 50% reduction in pesticide use. Local authorities are required to design cost-effective measures to minimize the impact of farmers' pesticides on water resources. A successful implementation of these new measures can only be achieved through a better understanding of the interactions between water, land use and the environment. One way of doing this is to calculate pesticide pressure and agro-environmental indicators (AEIs). However, this approach requires an effective information system that can process both the characteristics of the river basin and the agricultural activities using at least two embedded scales: the scale of the small agricultural catchment for action by farmers and the scale of a larger watershed for public decision making.

To this end, an environmental information system (EIS Pesticide) for pesticide issues was created using spatial data warehouse technology. This system allowed qualifying agricultural activities along with river basin characteristics. Specific spatial objects were designed to characterize practices at the relevant scales. The axes of analysis allowed providing results at different levels of integration, for different dimensions e.g. time, sprayed surface area, or pesticide type. The system was tested using datasets collected in the Charente watershed and its sub-basins and calculated pesticide pressure indicators on demand for each aggregation level defined.

1. Introduction

The European Parliament recently approved new European Union pesticide legislation, which introduces new regulations for the production and licensing of plant production products. These new laws also set out rules on the use of phytosanitary products, as amounts of pesticides are often found in ecosystems (soils and watersEU Member States are required to put in place National Action Plans to limit the "risks and impacts" of pesticide use on human health and the environment, including timetables and targets for reducing the use of plant protection products (PPPs). One such action plan – called "Ecophyto 2018" – has been introduced in France, and aims to achieve a 50% reduction in the use of PPPs by 2018. Institutional indicators have been defined to monitor the progress of these changes.

NODU, the first indicator created for France, is designed to measure nationwide sales of PPPs. It is supplemented by another indicator, IFT (treatment frequency indicator) which measures the intensity of pesticide application for individual plots or larger areas, for each crop type, based on the "number of approved doses" applied during a growing campaign.

Public money, provided to implement mitigation measures, needs to be used in the most cost-effective way possible. As the characteristics of agricultural activities, as well as natural conditions, differ across a catchment, appropriate tools are required to take in account this spatial variability, in order to evaluate the impact of change in land use or in agricultural practices on the water resources.

The first part of this paper focuses on the aims of the EIS Pesticides project and on the requirements for the information system, explaining the reasons for choosing a data warehouse model. Following this, the case study, carried out in the Charente river basin (South Western France) and sub-basins will be detailed. Then the concepts used in the generic conceptual model, and the

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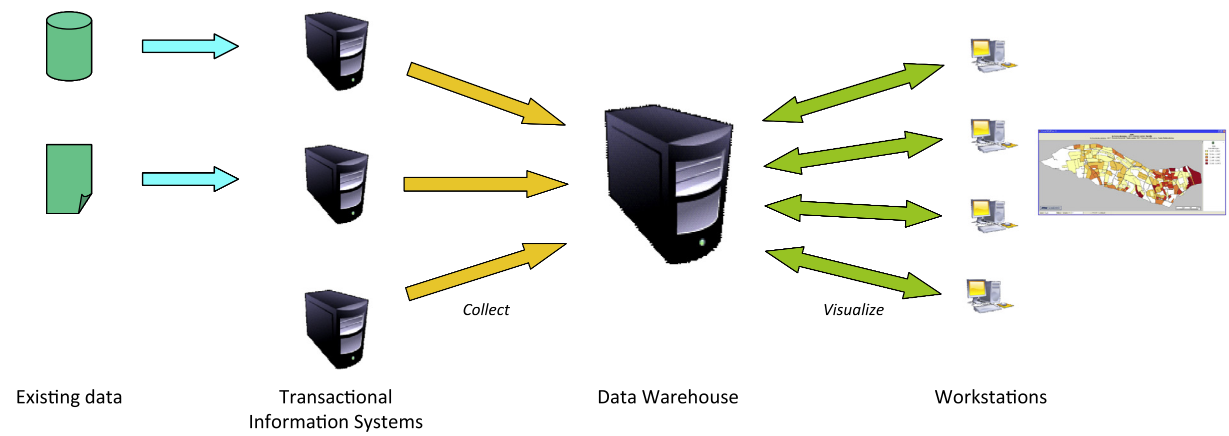

Fig. 1. Overview of data warehousing infrastructure – adapted from Miralles et al. (2010).

dimensions defined to analyze the spraying practices at several scales will be presented. Finally, some first results obtained using the data warehouse technology through the "Pesticide Cube" will be explained: the goal is to provide to stakeholders pertinent restitutions, giving them a clear spatial representation of the use of pesticides by farmers and the resulting effects on water bodies.

2. The EIS Pesticides project: general approach

The EIS Pesticides project involved Irstea[1] specialist teams in land and water management, along with computer scientists. The first goal of the project was to call up the experience of these teams and to pool their knowledge in the field of pesticide issues. The second aim was to develop an information system that could be used by both research teams and decision-makers, developed on the basis of case studies but which could be applied more generally. This information system had to combine data on agricultural practices (such as farm management and crop protection), useful information on watershed natural conditions, pesticide transfer, monitoring results, and data on mitigation strategies.

Several steps were needed to build the model. The first step was the design of a generic conceptual model, involving a lot of work by the specialist teams (land management and water management) to share and define the concepts to be used. The computer scientists were in charge of the development of the system. Once the conceptual model was completely described in UML, it was possible to implement it into a PostgreSQL database, tested by the two specialist teams with their field data. From this generic conceptual model, each specialist team programmed targeted analyses, taking into account specific issues relating to land and water management. The computer scientists chose to use data warehouse technology (Fig. 1) in developing these information systems, as this technology has previously proved to be effective in a decision-making context and for spatial and environmental issues (Pinet, 2010). Each specialist team needed also to define relevant axes of analysis and indicators[2] to design a specific data "cube" which will be implemented by the computer scientists. The axes of analysis or dimensions in data warehouse technology can be spatial dimension, temporal dimension and/or thematic dimensions. The indicators can be simple or composite, calculated inside the datawarehouse or uploaded at the lowest level of the dimension and then aggregated on the different level of the dimensions. For example, following the spatial dimension, these levels are often the different scales of decision. The present article is focused on one of the cubes built within the project i.e. the "Pesticide Cube" built to address land management issues.

The system which was needed could effectively analyze some agro-environmental scenarios, and calculate agro-environmental indicators on demand. A key requirement for the system was the ability to process data on at least two spatial scales: those of processes (a small catchment) and those of decision-making (a larger area where environmental action plans take place). Data warehouse technology has been used successfully to assess the impact of actions, practices, scenarios and programs from both a socio-economic and environmental standpoint (Schneider, 2008). It is reported to have been applied to agriculture by some authors (Nilakanta et al., 2008; Schulze et al., 2007; Yost, 2000). Nilakanta et al. (2008) present an example of data warehouse storing information on livestock (in India). Users can visualize (via tables) different data such as animal population, livestock production and performance. Schulze et al. (2007) presents a data warehouse designed in Germany for the storage of information related to dairy cattle breeding and milk production. One goal of the authors is to show the applicability of the data warehouse technology in the field of agriculture. The US Department of Agriculture's National Agricultural Statistics Service developed a data warehouse which brought together data from agricultural surveys and census data from ranchers, farmers, agri-businesses, and secondary sources (Yost, 2000). But the aggregation levels in this system are linked to financial or administrative boundaries (village, district, national level) and do not take in account environmental issues. The information about agriculture is collected through agricultural surveys or census and lower level estimates cannot be obtained from these with reliable precision.

These agricultural information systems do not allow users to visualize and analyze the geographical data on maps; these systems use a traditional data warehouse technology. In comparison, the recent technology called SOLAP (Spatial Online Analytical Processing) can display and process the georeferenced information of data warehouses. The SOLAP tool is defined as "a visual platform built especially to support rapid and easy spatiotemporal analysis and exploration of data following a multidimensional approach comprised of aggregation levels available in cartographic displays as well as in tabular and diagram displays" (Bédard, 1997). To the best of our knowledge, the system presented in our paper is the first SOLAP application in the field of agriculture. This novel type of applications has required an original and multidisciplinary development involving expert researchers in the field of GIS/SOLAP and in the field of agronomy. Currently, very few teams in the

[1] Irstea (previously named Cemagref) is a research institute of science and technology for Environment and Agriculture located in France (www.irstea.fr).

[2] The whole of indicators defined in the analysis model will constitute the facts of the fact table implementing the multidimensional cube.

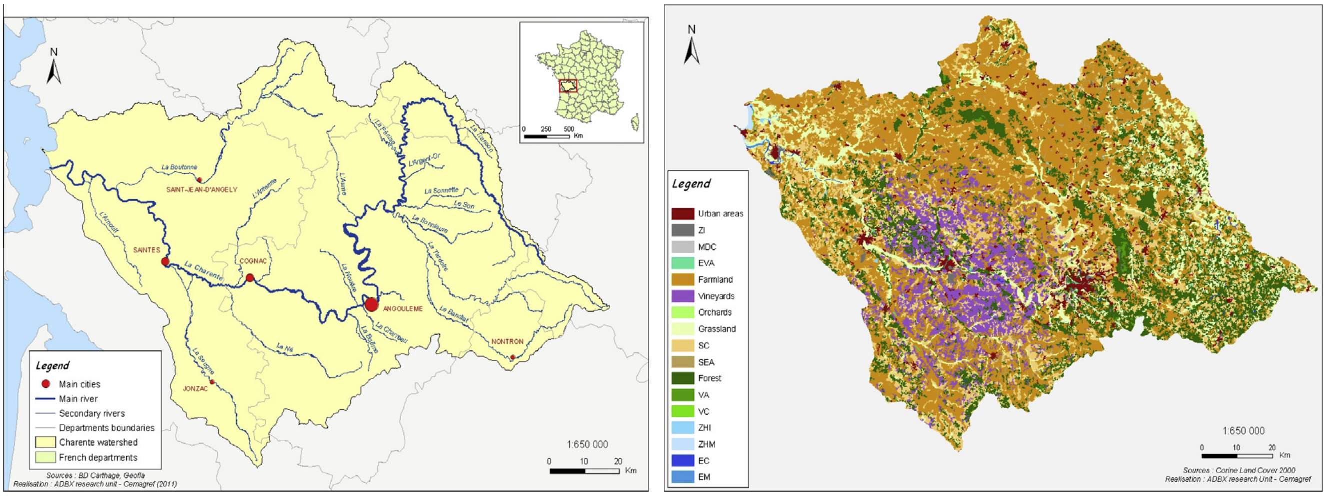

Fig. 2. Main rivers and soil occupation of the Charente river basin (Vernier et al., 2010).

world are experts in this field of SOLAP and no tool was available to help the modeling of SOLAP application. As presented in this paper, the computer scientists have developed specific UML-based tools to help users to design SOLAP applications to visualize and process georeferenced data using the data warehouse technology (Miralles et al., 2011). They showed that UML can help system designers to build a data warehouse model dealing with the use of pesticide in agriculture (Pinet, 2010). These tools were used to develop the information system and the Pesticide Cube (Fig. 1). The datasets collected in previous projects performed in the Charente river basin were used for the implementation of the system. The design of this information system was very briefly introduced in (Pinet, 2010). The details of the developed tool are provided in the present paper.

3. Presentation of the case study: the Charente river basin

The Charente river basin (10,000 km^2) (Fig. 2) is located in southwest France. Concerning water resources, the Water Framework Directive is a major current policy issue in European countries. Member States have to implement efficient measurement programs for each river basin district, taking account of the results of the analyses and studies carried out, in order to preserve or restore the ecological status of water bodies (by 2015). Fifty-two percent of the water bodies in the Charente river basin are at risk of failing to satisfy the requirements laid down in the Water Framework Directive (WFD), namely achieving "good" ecological status. This is due to high levels of agricultural non-point pollution (nitrates, suspended matter and pesticides) and frequent water shortages. The increasing frequency of low flow events since 1976 cannot be explained by climate change but only by anthropogenic pumping of water for irrigation (Giret, 2002). Moreover, inadequate management of fresh water has had an impact on salinity and coastal ecosystems.

Sixty percent of this area is farmland, of which 11% is irrigated. Forty percent of the Charente river basin's farmland is used for the cultivation of cereals, making it the second largest producer of this kind of crop in France. There are approximately 1.8 million acres of usable farmland and around 17,000 farms. Aside from cereal, a wide range of other crops are grown: protein oil (19%), vines (9%), animal fodder (12.5%), and assorted vegetables. The vineyard area is famous for producing Cognac and Pineau des Charentes (a fortified sweet wine). Cattle are also bred in upstream areas.

Maize is the most watered crop, accounting for almost 80% of the total irrigated area. Generally speaking, an irrigated farm will have a larger usable surface area, achieve higher yields, and will tend to use more intensive methods. In addition to the inorganic fertilizers, intensive agriculture consumes a wide range of pesticides in order to ensure both the quantity and commercial quality of products (cereals, fruits, vegetables, etc.). The vineyard area consumes the highest amount of pesticides per hectare and per year. Annual winter crops (wheat, rape) but also summer crops like maize, sunflower are also sprayed. Pesticide fluxes are transported from the small upstream watersheds into the river network, and then towards the coastal zone.

4. Datasets used for the implementation of the model

As our system had to be able to manage data at both the small catchment and decision making scales, we used a dataset from previous multi-scale research studies performed on the Charente watershed (Fig. 3).

Firstly, the results of a study carried out for the Ministry of Environment on the small Ruiné watershed in Charente were mobilized. Farm surveys and hydrological monitoring at the outlet (weekly measurements of fluxes of triazines and degradation products, diuron, glyphosate) were performed between 1996 and 2006. Risk indicators were calculated at the plot scale to confront results with farm diagnoses and water analyses.

On a larger scale, the results from two recent projects dealing with ICZM (integrated coastal zone management) were used. The European SPICOSA project[3] (Science and Policy Integration for Coastal System Assessment) proposed a system approach framework and integrated assessment platforms, dealing with the management of freshwater in the Charente river basin (Mongruel et al., 2011; Prou et al., 2009). The Respireau project (French National Program "Liteau") focused on the discussion process between scientists and stakeholders and dealt with the water quality issue (pesticide) in the same area (Vernier et al., 2010). These two projects led to the development of a typology of soils, hydrological units and farming systems within the Charente basin.

We collected data from statistical sources – Agricultural Census (RA), Common Agricultural Policy (CAP) and Graphic Parcel Register (RPG) – to characterize agricultural activities, as well as data

[3] Spicosa website: www.spicosa.eu.

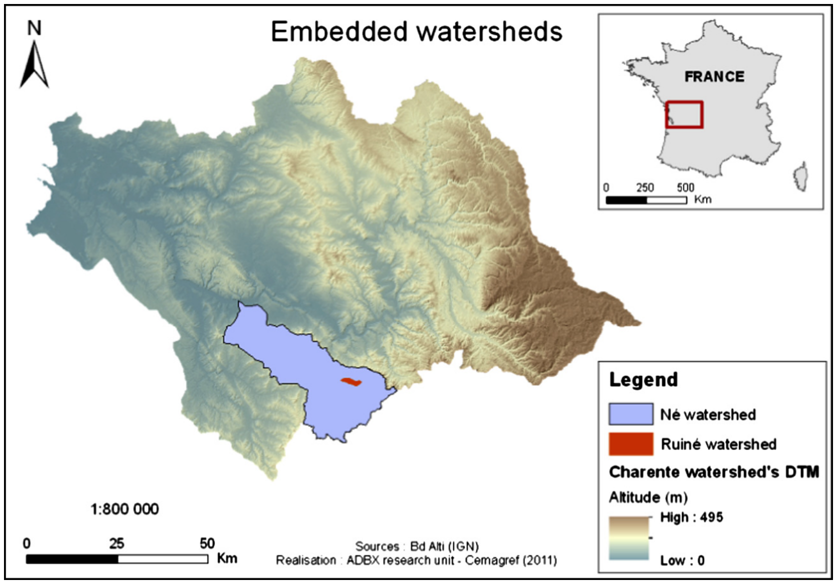

Fig. 3. Embedded watersheds in the Charente river basin (Ruiné, Né, Charente, ADBX, 2012).

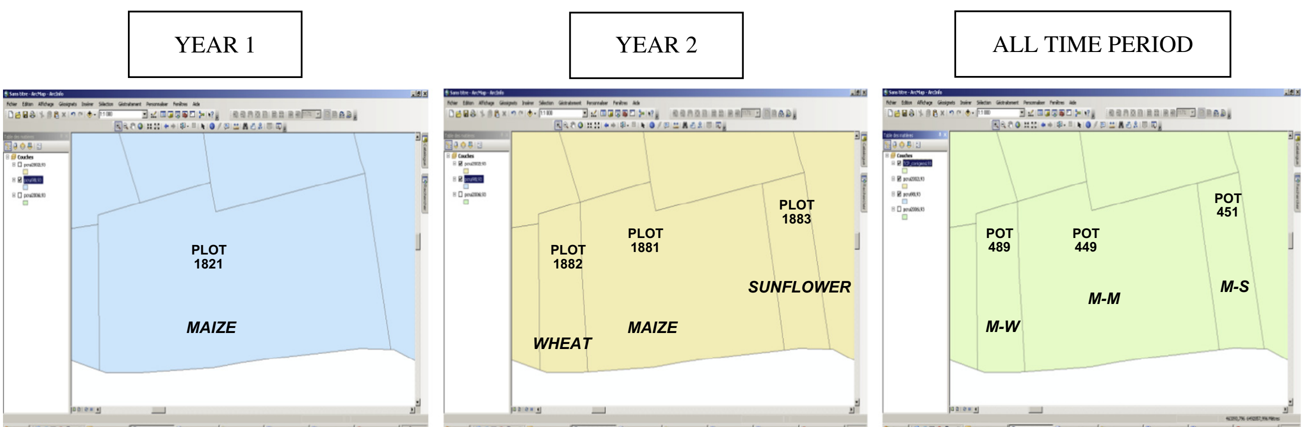

Fig. 4. *Plot-over-time* after 2 years in the rotation (ADBX, 2012).

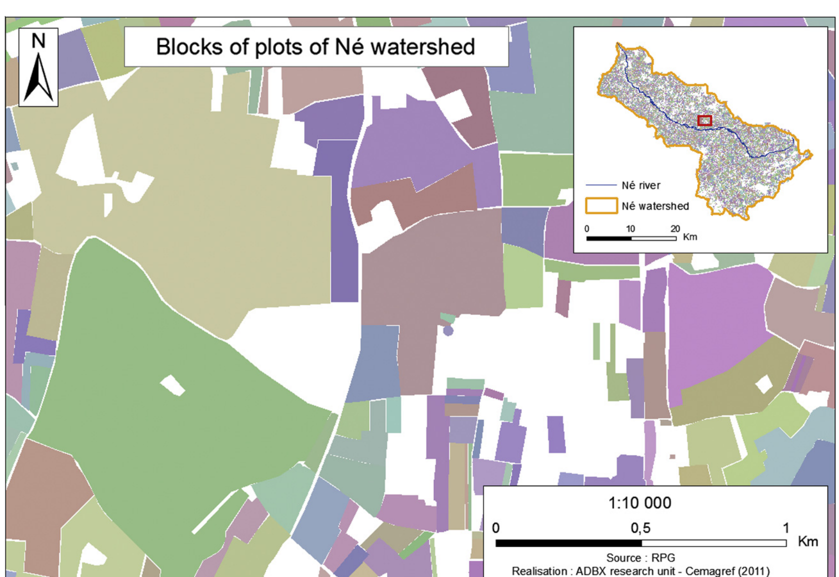

Fig. 5. An example of the spatial distribution of blocks of plots in the Né watershed (a sub-basin of the Charente watershed).

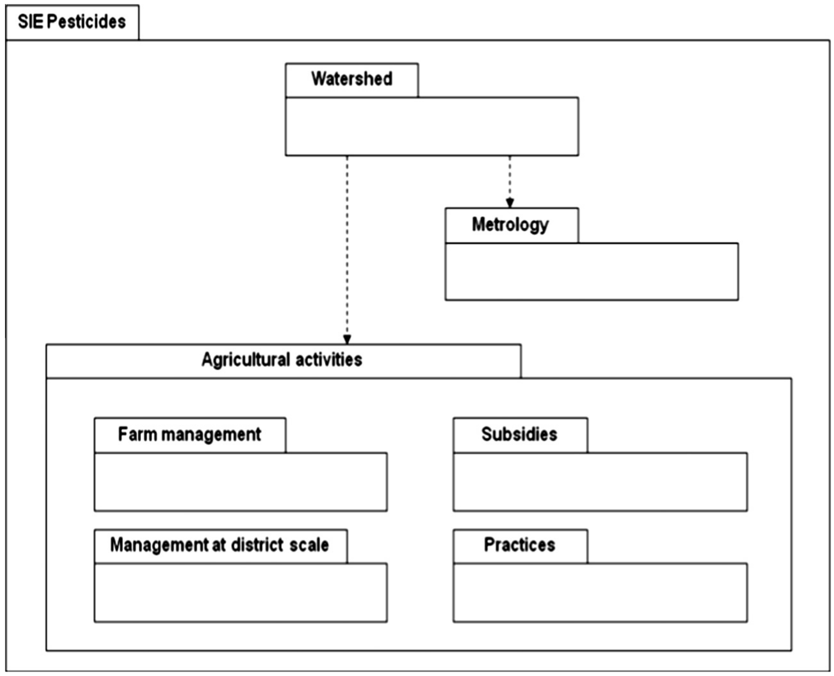

Fig. 6. The EIS conceptual model (UML) (from Pinet et al. (2010)).

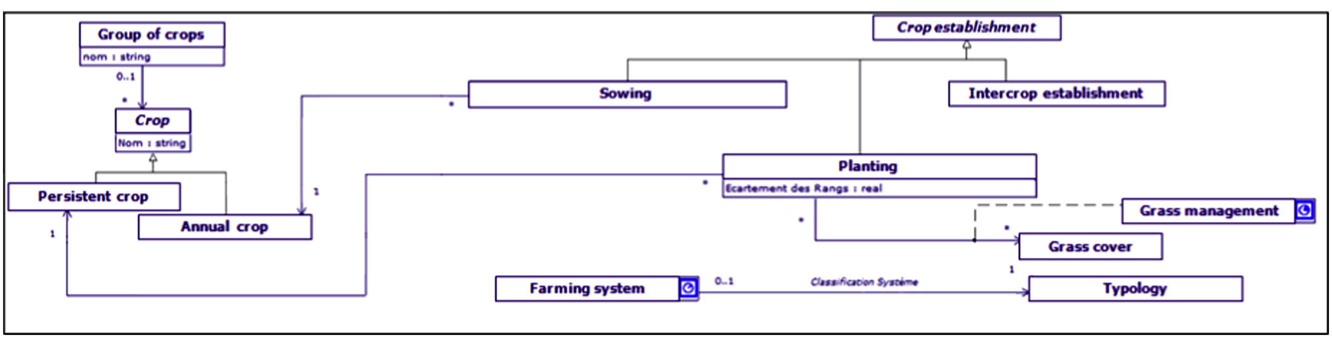

Fig. 7. Crop management package.

from surveys carried out among both experts in the field and professionals.

Another set of data was collected to characterize environmental conditions: these variables are needed to assess the potential risk of agricultural pesticide or nutrient transfers into surface waters. They concern structural sensitivity (slope, type of soil, distance to river, drainage, etc.).

Methods of clustering and data analysis were used within these two projects to define several typologies. Initially, a typology of hydrological units was defined using data about soil occupation and structural sensitivity (natural conditions). Then, using agricultural statistics, five main types of farming systems could be described: a livestock system, a mixed system (cattle farming, cereal farming, and vineyards), a cereal system (cereals and protein oil crops), a grapevine system and another crop system (cereals, protein oil and vineyards).

Linked to a simplified nomenclature of soils and results from surveys among experts, these typologies allowed defining a simplified representation of farming activities and allocating a crop management sequence including fertilization, pesticide spraying and irrigation for each main crop, main rotation and main type of soil of the area (Vernier et al., 2010.).

5. The conceptual model of EIS Pesticides

The spatial data warehouse were modeled in UML (Unified modeling language) with adapted spatial tools (Pinet et al., 2010). This visual formalism was implemented as a profile into the UML case tool Objecteering (developed by Softeam[4]). This profile is called the SOLAP Profile as described above. The use of UML in this project made the modeling of the data warehouse easier, and made for effective communication with the project participants, by giving a formal language to discuss the concepts, the objects and the links. The first step was to define the relevant scales and spatial concepts to be used in the model.

5.1. Spatial concepts used in the model

Territories and multi-scale management have become a subject of significant research interest for agronomists, notably due to growing environmental and landscape concerns, and – more recently – discussions on agricultural multifunctionality and territorial

[4] www.softeam.fr.

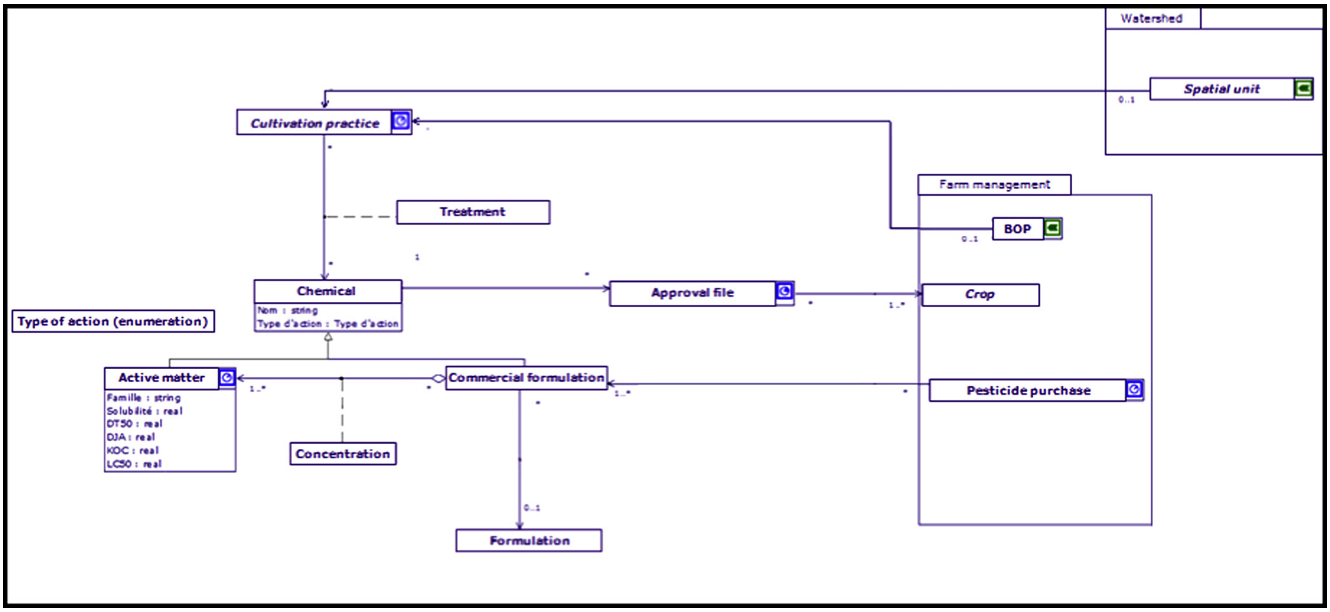

Fig. 8. Pesticide spraying practices package.

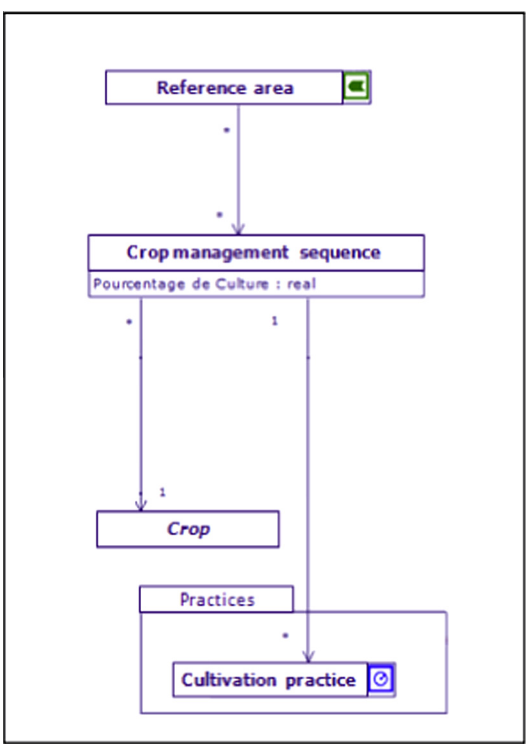

Fig. 9. Farm management at a larger scale package.

development (Mignolet et al., 2007). Some previous studies concentrated on the spatial distribution of agricultural practices within farming systems affected by environmental problems, for instance weed control practices at plot resolution over a water resource catchment (Biarnès et al., 2009). Others (Blavet et al., 2009; Ortega and Santibáñez, 2007) tested zoning methods based on soil fertility or runoff rates to delineate homogeneous management zones. From a methodological standpoint, reference spatial objects (RSO) (Wood et al., 1988) or new entities are hard to identify when selecting relevant organization levels. Different zoning methods have been used to create new entities aimed at identifying system units that function the same way at a given level. These have included partitioning of zones of similar appearance (Bindraban et al., 2000) or zoning according to stakeholders needs (Saqalli et al., 2009).

In order to characterize agricultural activities in our system, we used some predefined spatial delineations, as well as defining specific spatial entities. At the small catchment level, we consider homogeneous entities for rotations, farming operations, and crop management sequences. This entity is a constructed spatial object called *plot-over-time* (POT) (Fig. 4). It is obtained by intersecting the annual layers of crops on the catchment, over the time period studied. POT is a homogeneous unit for the analysis of agricultural practices over several years, characterized by the same crop management sequences, area, and cropping protection strategy (dates, commercial formulations). These data can be aggregated at plot level, which allows all annual plot layers to be rebuilt from the POT layer.

At the larger watershed scale, we used two other spatial entities in the conceptual model. The first one is the *block of plots* (BOP) in reference to an institutional French database, the RPG (Fig. 5). BOP is the elementary spatial unit used in French statistical surveys.

Another spatial entity used is the "reference area", a spatial unit where a type of crop management sequence has been defined using typologies in that area, or based on expert advice. This entity is needed to take in account the crop management at the district level.

5.2. Structure of the model

The EIS Pesticides model is a class diagram that includes several packages (Fig. 6) represented in UML, with additional spatial profiles extensions (similar to plug-ins). These packages relate to elements such as the characteristics of the watershed (natural conditions, slopes, soils, spatial entities, connectivity, etc.), different measurement types, and agricultural activities. The agricultural activity model is further divided into package for farm management, public subsidy, crop management sequences and pesticide practices, and farm management at larger scales.

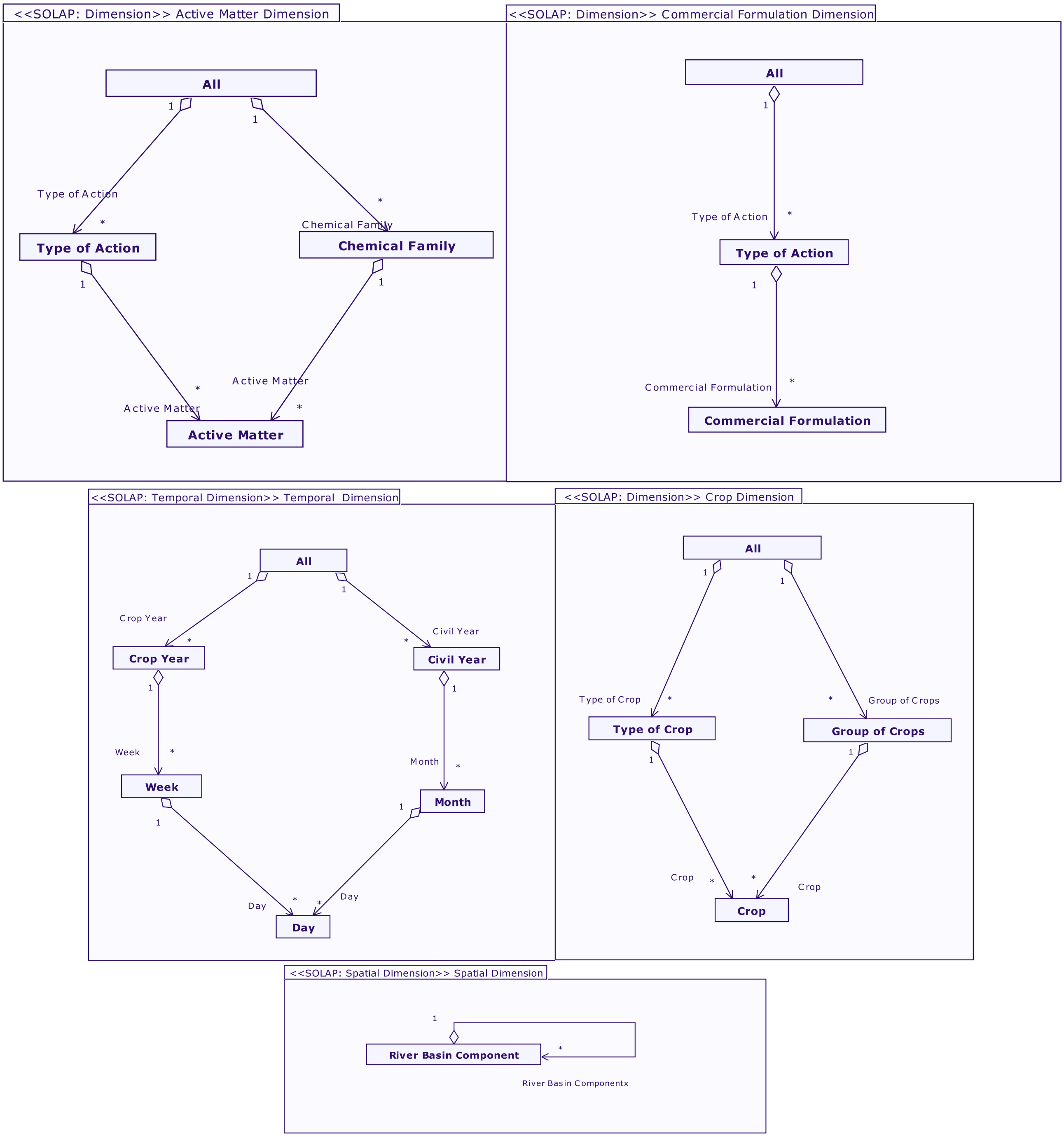

Fig. 10. All the dimensions of the Pesticide Cube.

Three different types of crops, along with all their characteristics, can be described in the farm management package: persistent crops, annual crops, and intercrops (Fig. 7). The system allows several crops, or a crop and intercrop to be recorded for a given campaign. The farming system relates to a typology that can be applied to the area. For persistent crops, the type of grass management can be recorded; note that the Grass Management class is an association class in the diagram. The nomenclature of the crops and crop groups is based on French institutional databases, and can be used to set parameters. Two crop rotation types are considered – predicted rotation (farmers' intentions) linked to the farming system, and "real" rotation (the succession of crops on the same plot).

The data needed to record agricultural practices are included in a specific package (package "practices" – see Fig. 8). This package is focused on pesticide spraying practices, even if alternative techniques can also be recorded. Both active matter (useful for the link to monitoring in rivers) and commercial products (for the calculation of French IFT) are taken into account. A link is made with the "crop" information, to consider reference doses – i.e. the amount of one type of product that farmers are allowed to spray on one particular crop. Other farming operations, such as irrigation, drainage, sowing, plowing, can also be recorded for any pre-defined spatial entity described in the model ("spatial unit" in the watershed package) and not linked only to the farm plot. Note that association

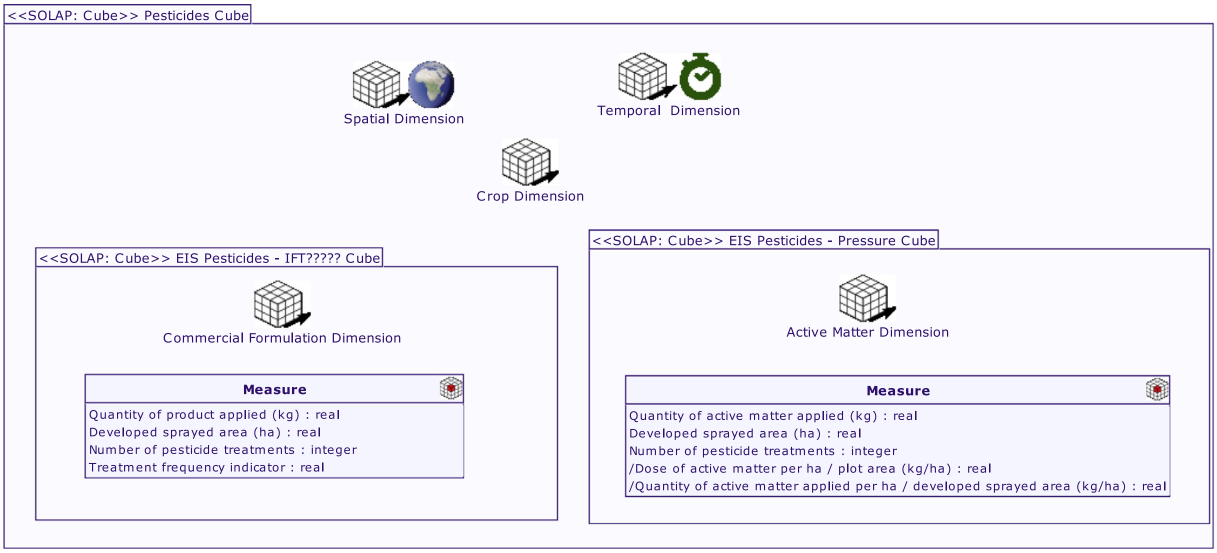

Fig. 11. The Pesticide Cube.

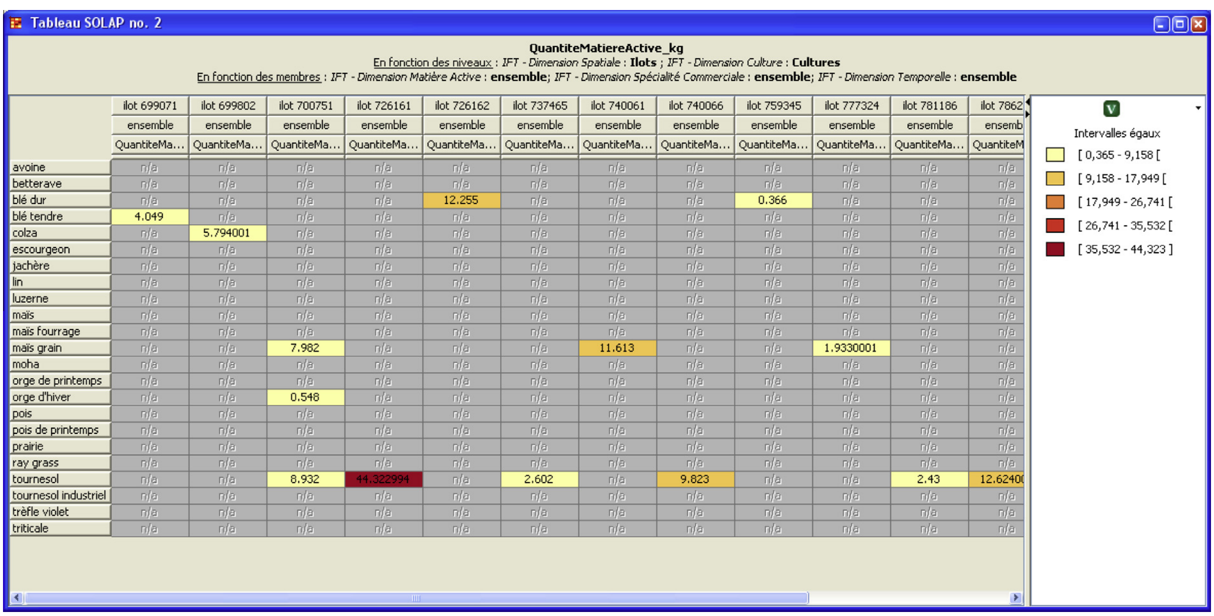

Fig. 12. Examples of restitution: Comparison of IFT values for specified plots and crops. Sprayed are per active matter in the all watershed.

classes are used to model treatments and active matter concentrations in the diagram.

The package "management at district scale" (Fig. 9) is used for describing agricultural activities and practices at a larger scale, on the basis of typologies or expert advice for reference areas. At this scale, it is not possible to allocate crop management sequences for each farm and each plot like in small catchments. This package allows the types of rotation and farming systems to be described, along with accompanying crop management sequences for a reference area. The information for describing the cultivation practices is exactly the same (link to the package "practices").

Another package is used to model subsidies (regarding BMPs and agro-environmental action plans). This requires further development (in progress within the Maeveau project). Currently, it is possible to record the area where action plans are running, the actions being funded, and the associated costs.

6. Definition of the Pesticide Cube

The next stage is to define the dimensions of the cube (Fig. 10) in order to provide relevant data analysis. In data warehouses, the criteria of analysis are structured in hierarchies called ***dimensions***. A data warehouse can provide results by combining different dimension levels. The elementary level (before any aggregation) is called "measure", and shows data – or a combination of data – in the model. In order to achieve relevant results, it is very important to choose correct measurements and levels of aggregation.

The Spatial Dimension takes into account embedded levels of watersheds (where on river basin component is included within another) from the fine level represented in our model by the plot-over-time to the upper level represented in our model by the whole Charente river basin. Embedded watersheds (Ruiné, Né, Charente) are taken into account.

The time dimension allows data to be aggregated over a set of weeks, which means that they can be partially compared over different seasons, crop years, or civil years, depending on the aim of the analysis being carried out (economical or linked to the hydrological events or to a campaign). The lowest unit level for recording farming operations or spraying activity is the Day. For instance, the upper level shows, all pesticides applied since records began. To analyze the actual substances sprayed, we defined two alternative axes. In the first of these, the finest level of granularity is active matter. In the second, commercial formulation is the finest level. These data were aggregated into action type (herbicide, fungicide or insecticide), or chemical family (e.g. triazine, carbamate, etc.). The second axis is used to calculate the French national Frequency Treatment Indicator (Ecophyto, 2018).

Finally, for the crop dimension, two levels of aggregation were chosen: crop type (annual, persistent, intercrops) and crop group (statistics).

Once modeled, the cube needs to be implemented. In our test, data from the Charente river basin, previously uploaded into the PostgreSQL database, were used to provide the elementary level of the cube (measures). This step could include the upload of data calculated in another system, for instance results of the simulations from an agro-hydrological model, considered as indicators of the water quality in the area. As part of the generation process, a database is also created. The physical structure of the data warehouse uses database technology. A function was developed in the SOLAP Profile that allowed cube models to be converted into database models. The layout of this database is shown in Fig. 11.

Through the Pesticide Cube, we can calculate a number of pesticide pressure indicators: quantity of active matter applied per plot area, plot area sprayed, quantity of commercial products, or active matter per hectare for all the spatial or time levels defined.

Calculation of the Treatment Frequency Indicator (IFT), requires both the legal and applied doses. Two "surfaces" are considered: the actual physical surface of the plot, and the "treated surface", which is the physical surface multiplied by the number of treatments carried out.

$$\mathrm{IFT\_plot} = \sum \mathrm{DA}(T) * \text{area sprayed}/\mathrm{DH}(T)$$

where DA is the applied dose and DH is the reference dose for the considered crop.

$$\text{Aggregation at larger scale}: \text{ average weighted with the area}$$

Using the data warehouse in this way, we can obtain the total amount of pesticide sprayed, or pesticide indicators for a given period, with varying levels of granularity.

7. Results of data analysis with SOLAP tool

Following implementation of the cube, and once loaded, data can be used by both expert users and those with no prior experience of this kind of system. A number of analyses are possible, combining different levels of granularity for the parameters included in the model, and making use of the pre-defined dimensions.

Data can be mined using the SOLAP aggregation tool, from the elementary "plot-over-time" level to the total watershed level. At each level, a number of operators are available (sum, mean, max, etc.). Analyses can also start at a larger scale and move down to the reference areas and blocks of plots, giving a better understanding of overall results.

With on-demand graphs, tables and maps, managers can better analyze the trends and results related to their action plans. For example, they can choose to display the quantity of pesticide applied over two sets of weeks or months, or compare 1 year with another. In addition to this, they can "navigate" through the different spatial dimensions with interactive maps. All of these tools make using the data warehouse very easy.

In the chosen examples (Figs. 12 and 13) the IFT is being compared with different plots based on crop type. It is possible to display (on any spatial level) the plot area sprayed with each type of active matter. For specific hydrological events (e.g. high concentration of certain substances recorded at specific periods) the type of molecule sprayed can also be spatially analyzed for that particular period (Fig. 14).

8. Discussion

Data warehouses are a family of computing tools allowing the combination of indicators representing the state of a system, an activity, etc. These computing tools allow handling simultaneously several indicators to describe a "facet" of the system (environment, agriculture, economy, etc.). Each indicator can be simple or complex. To well represent each facet of the studied system, it is often necessary to handle several indicators. Obviously, the combination of these facets gives a wider but more complex vision system. Moreover, if a temporal dimension was planned, it is possible to follow the evolution of the system. However, decision makers will handle all the indicators characterizing the system increasing the complexity of the decision.

Regarding agricultural policies, major reformulations recently occurred, making them more and more spatialised, for instance in the zoning for the implementation of BMPs. Defining policy priorities requires appropriate tools (indicators, models) with relevant results about the ecological and social features of agricultural practices. Through the participation of local managers in the action plans, and the analysis of emerging innovative practices implemented by some technical or professional groups, it is possible to identify realistic changes in farming practices, whose effects can be simulated and discussed.

The first results presented in this paper show that it is possible to produce simple spatialised pressure indicators, and an institutional one, the IFT, frequently used in the monitoring of action plans. It is possible to provide the indicators at several levels of granularity 'on demand' using the SIE database and the data warehouse technology. The SOLAP tools are needed to perform the required spatial analysis. But these simple indicators are not relevant enough to estimate all the environmental impacts of the

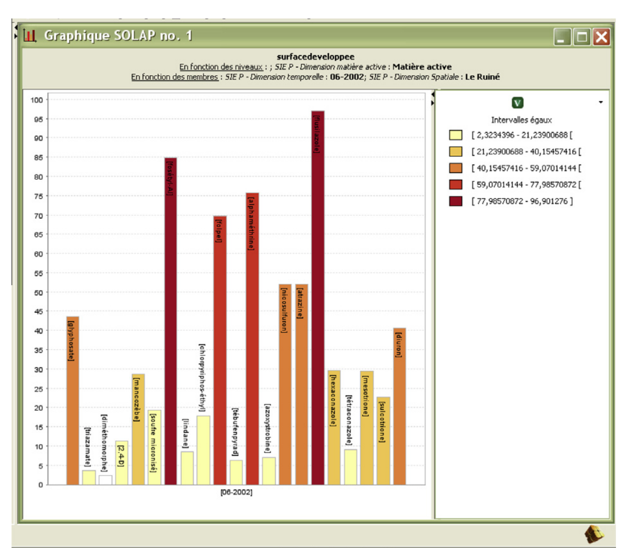

Fig. 13. Example of restitution: Sprayed are per active matter in the all watershed.

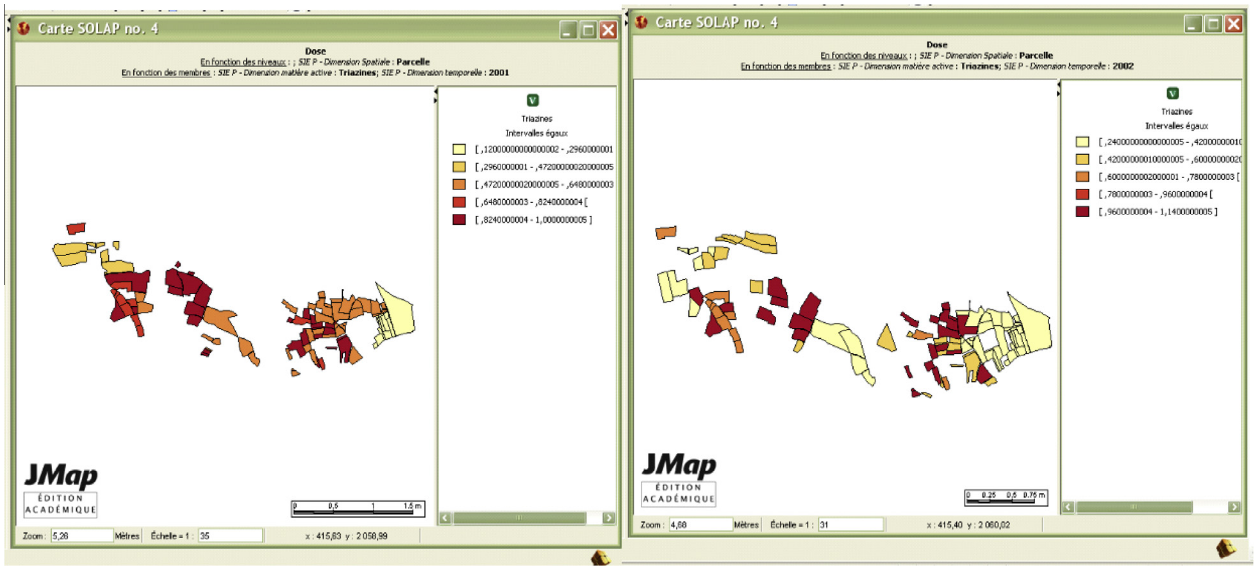

Fig. 14. Spatial repartition of the triazines sprayed in the watershed at the plot scale (2 years).

simulated agricultural practices. They are useful to estimate how the pressure from agriculture can be decreased but they do not help to evaluate if the potential risk of transfer towards water resources is decreased in the same way.

At least two types of agro-environmental indicators (AEIs) may be distinguished: simple indicators resulting from the measurement or the estimation (e.g. by a model) of an indicative variable and composite indicators that are obtained by aggregation of several variables or simple indicators (Reus et al., 2002). On the contrary, composite agro-environmental indicators provide an essential tool in formalizing information from different sources, and addressing the impact of agricultural production on the environment (potential risk of transfer to water bodies). These composite indicators have to combine information about agricultural activity and environmental conditions (data on climate, soils, hydrology, etc.). The current conceptual model takes into account all the required variables to produce AE indicators (in dedicated packages). Data mining is possible to obtain, for instance, the natural conditions of the most sprayed plots on the area. However, the indicator currently provided to stakeholders is the IFT indicator, which estimates a pressure (i.e. what is applied on a spatial entity) and the intensity of agricultural practices (i.e. the frequency of spraying, approved doses applied during the crop sequence). The goal is now to implement the calculation of this type of indicator into the EIS system, and make it available on demand. It could be possible either by calculating existing AE indicators inside the system (if all the variables are available) either by uploading them at the lowest level of granularity and working on the aggregation. This will allow various BMP scenarios and action plans to be assessed on both sector and plot levels.

9. Conclusion

The aim of the EIS Pesticide model was to provide an effective tool to evaluate the impacts of agriculture at different embedded watershed scales. The characterization of land use and farming activities, along with hydrology, soil, and natural conditions for several river basin components are included in the same database. UML made communication much easier between participants involved in the research project, who included both computer specialists and other scientists.

The model was shown to be reliable through a number of successful tests carried out with "real" datasets from the Charente watershed and two sub-basins (Ruiné, Né). The system fulfilled the specification to take different spatial scales into account. Using the SOLAP tool, we calculated and aggregated pesticide pressure indicators at varying levels of granularity.

Tests are currently underway on a larger number of sub-basins, as part of a new research project, concerned with the evaluation of agro-environmental mitigation measures.

Using the levels defined in the time dimension, agricultural practices can be analyzed over a much larger range of periods, leading to a much clearer understanding of how an action plan is progressing. Various hypotheses can be tested, helping decision-makers respond to special requests from stakeholders. The further development of the system implies to use characteristics from the river basin sub-system in the model to calculate agro-environmental indicators, combining vulnerability and pressure.

The data warehousing seems useful in creating decision-making tools in the context of agro-environment action plans and evaluating "ex-ante" the potential impacts of the evolution of agriculture on the area. With the aid of this technology, those in charge of public policies can make more informed decisions when managing sensitive areas, or when implementing mitigation measures.

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