Stages and activities of the projects that give rise to models for agricultural development

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Abstract

Developing system models for agricultural development is time consuming. Efficient use of resources requires that one anticipate the various activities of a modeling project. The purpose of this paper is to provide an aid for the planning and execution of modeling projects by presenting how 20 different modeling projects in France were carried out. We can distinguish two types of project. The first group aims at the development of decision support software for farmers or extension personnel for application to their specific situation. The second group aims at developing software which will be used by researchers and agricultural engineers to evaluate agricultural production systems over a range of typical situations. To be efficient, it is important to clearly define the type of project from the start.

Keywords: system model; agricultural development; project management; decision support system.

Introduction

System models, that describe mathematically the evolution of interacting system components, have become essential tools for agricultural development (see for example Ahuja *et al.* 2002). Most of the literature concerns presentation of models, calibration, evaluation or use of models. Furthermore, the literature concentrates on results rather than process, and so is not very informative about how to carry out a modeling project. It is important to emphasize the difference between the notions of project and model. A project has a beginning (project initiation, when a group of partners agree on an objective) and an end (when the software or the results of the model are made available). The same model, that is the same equations describing a system, can be used in several projects.

There is abundant information about project management in general (Verzuh, 2008). As concerns process models more particularly, several textbooks include a summary diagram of the steps in model development (Overton, 1977, Haefner, 2005, Zeigler, 1979, Barnes & Fulford, 2002). Refsgaard *et al.* (2005) proposes a set of guidelines for modeling in hydrology, in order to help in planning and carrying out such a project (Table 1).

Information on how actual modeling projects are carried out would however be useful for new projects. One could compare one's project with others, in order to borrow ideas from these other projects or at least compare one's methods with those used elsewhere.

Table 1. Stages of a modeling project according to various authors

(Verzuh, 2008)	(Refsgaard *et al.*, 2005)	(Overton, 1977)	(Zeigler, 1979)	(Haefner, 2005)
Define	Model study plan	Specify model objectives	Specification of objectives and available knowledge	Formulation
Plan	Data and conceptualization	Identify submodels and subobjectives	Modeling	Verification
Execute	Model set-up	Construct and validate submodels	Simulation	Calibration
Close out	Calibration and validation	Assemble submodels and validate	Validation	Analysis and Evaluation
	Simulation and evaluation	Address initial questions		
		Sensitivity analysis.		
		Validate those causal structures/parameters		

The purpose of this paper is to aid in organizing modeling projects by presenting such a compilation, based on a survey of modeling projects for agricultural development which was carried out in France in 2008. For a new modeling project, the most important choice is the type of modeling project in order to concentrate effort on priority stages.

Materials and methods

The questionnaire was sent out to the partners of a French modeling network for agriculture (RMT modélisation, www.modelia.org) which includes researchers in the French National Agricultural Research Institute (INRA, research institute) as well as in all the major technical institutes for applied plant and animal research. Detailed questionnaires were returned by 20 different projects (Table 2). All of these projects concern "management models" rather than "research models" (France & Thornley, 1984, p. 11). Most of the responses concern projects currently underway.

The questionnaire proposed stages of the project, allowing the respondents to define by themselves a different list of stages, in order to identify the structure of each. It contained detailed questions to understand how specific activities were carried out.

The survey was restricted to projects aimed at using system models for agricultural development. The projects for which responses were obtained are listed in Table 2. They include models of pest or disease dynamics (10 of 20), crop models and livestock models, or combinations of those. 8 projects concerning pest and disease conducted by the fruit and vegetable institute (CTIFL) have a number of similarities ("the CTIFL projects"). The projects SeptoLIS (Gouache and Couleaud, 2009) and CryptV also concern diseases. The large representation of crop protection models reflects the fact that crop protection is a major application of modeling in agronomy. An inventory in France in 2009 found over 120 different modeling tools related to plant protection (FNLON *et al.*, 2009) and a similar inventory at the European level in 2007-2008 listed and analyzed about 70 tools for weeds, pests and diseases on crops (Been *et al.*, 2009).

Table 2. The modeling projects in this survey.

Name[a]	Objective
Type 1: specific context project	
Carrot Alternaria (CTIFL[b], 2010)	Develop model for evaluating disease pressure of alternaria on carrot.
Leek Thrips (CTIFL, 2010)	Develop model for evaluating population of thrips on leeks.
Lettuce Mildew (CTIFL, 2010)	Develop model for evaluating disease pressure of mildew on lettuce.
Walnut Bacterial Blight (CTIFL, 2010)	Develop model for evaluating disease pressure of bacterial blight on walnut.
Peach Thrips (CTIFL, 2010)	Develop model for evaluating population of thrips in peach orchards. CTIFL
Codling Moth (CTIFL, 2010)	Develop model for evaluating population of codling moth in apple orchards. CTIFL
Strawberry Oidium (CTIFL, 2010)	Develop model for evaluating disease pressure of oidium on strawberry. CTIFL
Leek Rust (CTIFL, 2010)	Model leek rust population dynamics
CryptV (IFV[c])	Model vine diseases
SeptoLIS (Arvalis[d], Gouache *et al.* 2009)	Develop model to help deciding on fungicide treatments
Ventilation (IFIP[e])	Model energy consumption for heating and ventilation of animal buildings
ATEC (IE[f])	Simulate production of goat herd
Vineyard water (INRA, Pellegrino *et al.*, 2006)	Provide diagnosis of performance of vineyards based on indicators of water stress
Type 2: Representative context project	
SIMBAL (INRA, Agabriel & Ingrand 2004)	Study the relation between management and performance of milk herds
GENESYS (INRA, Colbach 2009)	Model effects of cropping system on gene flow in landscape
ALOMYSYS (INRA, Colbach *et al.*, 2006, 2007)	Model effects of cropping system on population dynamics and natural selection of weeds.
Azosystem (INRA, Cannavo *et al.*, 2008)	Evaluate nitrogen losses in field
Winter Rape (CETIOM[h], Jeuffroy *et al.*, 2006)	Estimate yield and oil content of winter rape unstressed or under water and/or nitrogen stress
MELODIE (INRA-IE-IFIP, Chardon *et al.*, 2007)	Evaluate environmental impact of milk cow or pig farms
SIPPOM (INRA, Aubertot *et al.*, 2006)	Simulator for Integrated Pathogen Population Management Study effect of spatial arrangement of cropping systems on pathogen adaptation to resistant varieties

a. Short name with main reporter and reference
b. Centre Technique Interprofessionnel des Fruits et Légumes
c. Institut Français de la Vigne et du Vin
d. Arvalis-Institut du végétal
e. Institut du porc
f. Institut de l'élevage
h. Centre technique interprofessionnel des oléagineux métropolitains

Results

Two types of project

Based on an analysis of the different projects, we found that the projects fall into two categories, with strong similarities between the way projects of the same category are carried out and important dissimilarities between categories.

The first type of project aims at providing a tool for use by farmers, extension or professionals. The major identifying characteristic of these projects is that they are designed to apply to the specific conditions of interest to each user. For example, if soil variables are an input to the model, these projects use soil data of the user in question. If the model uses current season weather, then the most relevant and most current weather data are used. If the model depends on herd composition, then the specific characteristics of the user's herd are used. In some cases, the model itself is made available to users. In other cases, it is the results of running the software that are made available (for example, through maps of disease risk or severity which are published at regular intervals). We will refer to these projects as "specific context" projects.

The second type of project aims at studying types of situations rather than specific situations, in order to better understand and evaluate different production systems. The software developed is meant for researchers and engineers. Another possible objective here is to test the feasibility of decision tools, which could be made available to farmers, extension or professionals in the future. The models in these projects could in fact be used for any specific context. It would simply be necessary to input the data for that context. However, the software is not particularly designed to facilitate use with many different contexts. We shall see that these projects differ from specific context projects in many other ways as well, and not only in the way the software handles input. We will refer to projects of this second type as "representative context" projects.

For crop models there is often a distinction made between applications for research and applications for on-farm decision making. For example, in the book edited by 0and Stephens (2002), part 1 is entitled "models as tools in research and part 2 "models as decision-support tools". Sivakumar and Glinni (2002) distinguish "model applications for on-farm decision making" , "model applications for research" and "model applications for policy management". Our specific context projects seem to correspond quite closely to what is usually meant by applications for decision support. Our representative context projects fall within model applications for research or for policy management, though those categories are usually much broader than what is intended here. In particular, we have excluded applications where the goal is to obtain a better understanding without an explicit goal of better decisions.

Table 2 assigns each of the projects studied here to one type or the other.

Duration

Table 3 shows the distribution of reported total duration times for the different projects (estimated in the case of projects still underway). This represents the time from project initiation up to the time when the software becomes available for its intended use, either by outside users or by the project team. In some cases the end point is not clear cut, because software use may begin while software development continues. With a single exception (the Ventilation project, which involves simply translating the text of an existing model from Danish into French), projects take at least 3 years and often much longer. This confirms the

idea that developing a model is a major undertaking, and emphasizes the importance of project management.
The two types of projects (context specific or representative context) do not seem to systematically differ in duration. However, as we will see below, the way effort is divided among the stages of a modeling project is quite different for the two types.

Table 3. Project durations

Duration (years)	Number of projects
1-2	1
3-4	6
5-6	2
7-8	3
9-10	2
11-12	1

Stages and activities of a modeling project

The stages of a modeling project identified here are shown in Fig. 1.

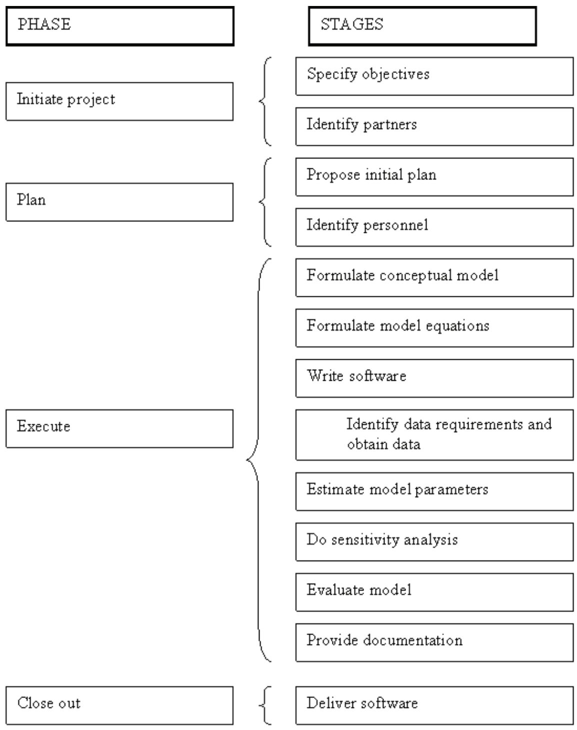

Figure 1. The stages of a modeling project identified in this study. This is basically similar to the stages identified elsewhere (table 1).

We consider the project stages in the order in which they are often undertaken. However, in almost all cases there are also loops, where one returns to previous stages, and cases where several stages are undertaken simultaneously.

Specify objectives

A project begins by specification of the objectives of the project including the use of the software tool that will be developed as well as the targeted users.

The specific context projects are intended to provide decision support tools for farmers, extension personnel or other professionals. For example, the CTIFL projects aim at providing information on pest or disease population levels. The objective is to provide farmers or extension personnel with information specific to each context, which can be used as the basis for deciding whether or not to treat against the pest or disease. Another example is the SeptoLIS project, where the objective is to predict the level of the septoria tritici blotch disease on wheat using up-to-date weather from multiple locations throughout northern France, again as the basis for crop protection decisions. The Vineyard project aims at developing a software tool for evaluating the consequences of water stress in any particular vineyard. In the ATEC project, the goal is to provide a tool for evaluating the milk production performance of a goat herd, and for evaluating feed requirements. The user inputs the specific population characteristics of his goat herd. The software predicts milk production of a problem-free goat herd with the same characteristics under standard management, which can be used as a reference. The Ventilation project aims at providing a tool to evaluate ventilation and heating systems for livestock buildings. The software can be used to evaluate existing systems or to test proposed modifications to those systems.

The representative context projects in general aim at ex ante assessment of a range of management practices, and are aimed at a small number of researchers or agricultural engineers as initial users. The aim is to study types of situations rather than a large number of specific situations. The Azosystem project aims at evaluating the effect of crop management practices on nitrogen losses. The objective of GENESYS is to provide a tool for exploring the effect of management and crop rotation on gene transfer between fields. SIMBAL aims at providing a tool to study how production and reproduction in a beef cow herd depend on management. The objective of MELODIE is to create a tool for studying how management affects the environmental impact of integrated dairy, swine and crop farms. SIPPOM aims at developing a tool for studying the relation between crop management on the scale of a landscape and the conservation of resistance to plant pathogens.

Identify partners

Since modeling projects are in general rather major undertakings, they often involve several partners from different organizations with different roles.

Our survey clearly showed that the type of partnership is different for specific context as opposed to representative context projects. The details however are rather specific to the organization of agricultural research in France, which is divided between INRA and the technical institutes.

The specific context projects in general involve either just a technical institute or a technical institute associated with one or more professional organizations. For example, the Leek rust project involves the technical institute CTIFL and the professional organizations SILEBAN and FREDON Nord Pas-de-Calais. Financing for these projects is generally provided by the technical institute. Partnership with local professional organizations is of particular interest in this type of project, since it helps insure that the final product is adapted to the needs of the profession. In several cases, it is in fact the professional organization that first identified the need for a decision support tool.

In all the representative context projects, INRA is the major partner, usually in collaboration with one or more technical institutes. Financing (other than the salaries of permanent personnel) often comes in part from outside contracts or from the technical institute. INRA is in general responsible for developing the model and the technical partners provide information about current practices. The dialog between researchers and the technical institutes is an other important benefit of this type of project.

Propose initial plan

The projects reported here usually start with a general outline of how the project will be conducted and with an estimate of project duration. Often, however, the outline and duration are not very detailed. Time overruns seem to be quite common.

The CTIFL projects, for example, do not include an exact termination date. In particular, it is not fully decided in advance how many years of field experiments will be required for evaluating the model. The SeptoLIS project was initially planned for 3 years, but a revised program is adopted each year, with a detailed description of the work to be done during the year.

The representative context projects are in general even more difficult to plan in advance, since the time required to develop a satisfactory model is inherently uncertain. Several of the projects note that the project overran substantially the initial duration estimates. The Winter Rape project states explicitly that the initial planning was much too optimistic. The modeling work was anticipated to last a few months; instead it took a few years. Since then, this project has instituted a new planning phase at the end of each work period. The MELODIE project identified four project groups that could work simultaneously, with responsibility for respectively overall model architecture, for animals and feeding, for manure and finally for soils and crops. Here again it is noted that the initial calendar was too optimistic.

Identify personnel

It is necessary to identify the personnel who will be involved in executing the project. There are quite clear differences between the specific context and representative context projects, but it is hard to separate the direct effect of the type of project from differences that arise from the way the technical institutes and INRA operate.

The specific context projects in general use permanent personnel, and have specialized personnel for the different aspects of the project. The CTIFL projects for example typically involve an engineer who is responsible for both the model and software development, a collaborating engineer who is familiar with the crop, plus field personnel responsible for carrying out experiments to test the model.

The representative context projects in general rely more heavily on temporary personnel. There is in general a researcher in overall charge and a group of experts who follow the project, but the bulk of the modeling and programming is often done by a thesis student, contract personnel and/or students doing internships. For example, the Winter Rape project involves 2 INRA researchers and 3 engineers from two different technical institutes, each for a limited amount of their time, and two contract engineers who worked on the model. The MELODIE project relies on two doctoral students.

Formulate conceptual model

Before actually writing the model equations, one generally makes some general decisions about the model. What exactly is the extent of the system modeled (or more specifically, what are the state variables)? What are the explanatory variables? What is the range of conditions that is modeled? The model at this stage is a conceptual model.

In the specific context projects, the number of state variables and explanatory variables is usually relatively small. CTIFL projects, the state variables concern only the population of an insect or disease. Only the effect of climate on the population is taken into account, without explicit effect of the crop. The state variables of the model in the ATEC project are milk yields for different groups and categories of animals as well as number of animals. The explanatory variables are the animal characteristics such as number of births, maximum duration of milk production and the parameters of the milk production curve.

The models in the representative context projects generally describe systems with more components, and therefore have more state variables. Furthermore, these models in general include system management among the explanatory variables, because exploring the effects of different management strategies is a major objective.

The model of the Azosystem project describes the crop and the soil. The explanatory variables include meteorological variables, soil characteristics and crop management variables. The state variables of the model in the SIMBAL project are animal numbers and weights. The explanatory variables include the characteristics of the animals and also livestock management practices.

Three of the representative context projects concern systems with particularly many state variables. The SIPPOM and GENESYS projects concern a number of interacting fields, so there are state variables representing the state of each field. Among the explanatory variables are crop management variables for each field. The model in the MELODIE project concerns a mixed livestock and cropping farm. The state variables concern all the fields and each lot of livestock. In this model management is described by decision rules, so instead of inputting management decisions as explanatory variables, management decisions are calculated from other explanatory variables.

The specific context projects did not produce diagrams to represent the conceptual model. About half the representative context projects did produce diagrams. In some cases these were Forrester diagrams, where the system is represented as a set of tanks connected by pipes with vents which can regulate the "flow" of material from one tank to another (Haefner, 2005). Another type of representation, which is closer to the computer implementation of the program, is the set of UML diagrams (Papajorgji and Pardalos, 2006) representing static or dynamic views of the system. The SIMBAL and MELODIE projects produced UML diagrams.

Formulate model equations

The activity here is to write the detailed mathematical equations of the model. In fact, the models in all the projects here are based at least in part on existing models which have been published in the literature. Thus many or even most of the equations are taken from an existing model. This activity is thus much less demanding than it might at first seem.

The CTIFL models are either directly based on existing models or are adaptations of existing models to new situations. The model in the Carrot Alternaria project is a model used in other countries and the Walnut Bacterial Blight model is based on a preceding model called

Xanthocast (Adaskaveg *et al.*, 2010). The SeptoLIS model is based on a model in the literature (Audsley *et al.*, 2005), with minor modifications.
The models in the representative context projects are not in general based on a single existing model, but rather involve coupling several existing models. These projects also in general require original modeling for certain aspects of the overall system. For example, the Alomysis model uses a piece of an existing model for soil structure, and aspects of another for describing the movement of soil elements under tillage. The principles in yet another model are used to describe plant growth in the period from germination to emergence. The model in MELODIE combines existing models of livestock dynamics, of livestock dejections, of cow intake and of crop growth and development.

Write software

Once the equations are specified, they are embedded in software which does the calculations. In fact, the model equations are often only a small part of the software. Other major elements involve input of explanatory variables, output of intermediate or final results and an interface that allows the user to specify what type of calculations he wishes to do.
Software development is in fact a project in itself with a very rich literature (as just one example, McConnell, 2004). It is necessary to define the specific objectives of the software, then execute the software development project and deliver the software. Here we only consider certain aspects of this activity.
The technical institutes CTIFL, Arvalis and IFV have modeling platforms to which new models can be added. The platforms handle input/output, share a uniform user interface and provide the models as web applications. This very substantially reduces the amount of programming necessary for a new model.
The representative context projects on the other hand in general involve developing stand-alone software rather than use of a modeling platform. As noted, some of the components of the overall model may be recovered from existing models. In some cases existing models can be used as is and coupled to other modules, in other cases the existing models are reprogrammed. Many different programming languages are used (Visual Basic, C, C++, Java, Mathlab or a mix of them).
In the specific context projects, the person responsible for programming is, in most cases, a permanent employee of the technical institute. In the representative context models on the other hand, temporary personnel is often used which can be considered as a potential source of difficulty.
None of the projects report a formal verification plan for the software. Testing the software is in general done by carefully examining the code and the output.
Software development is in general a relatively minor part of specific context projects due to the use of a platform reducing the programming needed for a new model and partly due to the fact that the model does not in general evolve much from its initial formulation. For example, in the Peach Thrips project the model was developed, coded and added to the CTIFL model platform in the second year of the project, then the following 6 years were devoted to field experimentation for testing the model.
Software development on the other hand is in general a major part of representative context projects. In the SIMBAL project, with the same overall duration as the Peach Thrips project (8 years), the entire period was spent on model and software development. A particular difficulty that was noted for this project concerned the way to model management decisions. Typically

in representative context projects there are multiple versions of the model, and so multiple versions of the software.

Identify data requirements and obtain data

Obtaining data is often a major activity of a modeling project. For developing model equations, for estimating model parameters, or for model evaluation, one needs historic data that include the values of the model explanatory variables and also observed responses. For predictions, one requires just values of the explanatory variables.

In specific context projects, the model is in general closely based on an existing model, and so no experimentation is required to determine the basic functions in the model. In representative context projects on the other hand, there can be experimentation to help formulate the model (example: ALOMYSYS, GENESYS and SIPPOM projects).

In almost all cases, the majority of model parameters are taken from the literature or from an existing model. However, some experimentation may be necessary to obtain a few missing parameters from some specific controlled environment experiments for CTIFL projects or by calibration by fitting the overall model to historic data for SeptoLIS project. Similarly, the representative context projects may involve some experimentation to obtain specific parameters and/or calibration.

Model evaluation may also be based either on new specific experiments or/and on recovery of past experimental data. The SeptoLIS model uses both recovered past and new data on untreated fields in multiple locations to test the model. The data are collected from networks of experimentations to obtain a representative sample.

In the representative context projects, there can be specific experiments for testing the model partially (Winter Rape, ALOMYSYS), but more generally one uses existing data, even though they were obtained for a different purpose (Azosystem, GENESYS, SIMBAL, SIPPOM) and may not be representative of the situations of interest.

In order to simulate with a model, input data are required. In type 1 projects one needs the input data for the specific situation of the user: daily weather up to the current day, soil characteristics, initial conditions and the specific management for the specific use. Animal models might require herd characteristics, feed amount and quality, etc. Obtaining required data from the user, or retrieving data from data bases, is a major aspect of specific context projects. For example, this may require coupling real-time meteorological data to the model, and allowing each user to use it for his situation.

In representative context projects, the problem of input data is quite different. These projects identify scenarios and use the model to evaluate them. These scenarios are "representative" of a range of situations, but do not need to be identical to any particular situation. For example, this kind of model does not require updated weather data. One can use fixed past climate series. Note however that defining a set of representative situations may be quite difficult. Thus building a data base for representative context models poses different problems than those involved in providing the data for specific context projects.

Estimate model parameters

In almost all cases the majority of model parameters are taken from the literature or from an existing model. For the remaining parameters, essentially two approaches are used.

In some cases, one can isolate a specific process and study it experimentally. For example, one can measure latency times of fungal development for different constant temperatures and from that estimate the parameters in the relation between latency time and temperature (CTIFL projects). The ATEC project obtained all the parameters of the lactation curves from a new analysis conducted specifically for this project. The ALOMYSYS and GENESYS projects also obtain some parameters from new experiments aimed at studying specific processes.

In other cases, the parameters are obtained by calibration. This involves fitting a model to data which is the result of many processes. Most of the model parameters are fixed at values obtained elsewhere. The few unknown parameters are estimated by finding the values which give the best fit to the data (Example: SeptoLIS and SIPPOM projects). For a general discussion of model calibration see Makowski *et al.* (2006).

Do sensitivity Analysis

Sensitivity analysis studies how much variability occurs in model responses as a result of variability in inputs, where "inputs" refers to model parameters and/or explanatory variables (Saltelli *et al.*, 2000; Monod *et al.*, 2006). The objective is to better understand how the model responds to different inputs, or to determine those inputs that have the greatest influence on the outputs or to determine which parameters to calibrate.

Of the specific context models here, only SeptoLIS involved sensitivity analysis. Among the representative context models, sensitivity analysis was undertaken in the Winter rape, ALOMYSYS and GENESYS projects.

Evaluate model

This stage refers to evaluation of the model (and not to evaluation of the overall project). For reviews of the various facets of evaluation for models in agronomy see Wallach (2006) and Bellocchi *et al.* (2010). Two notions are very important here. First, it is important to distinguish between evaluation of adjustment and evaluation of predictions. Suppose that some model parameters are adjusted to give the best fit to the data. The fit that can be obtained measures adjustment quality. It is then necessary to test the model on independent data to determine prediction quality. It is generally prediction quality that is of real interest. The second important notion is that of target population. This is the set of conditions for which one will use the model. Clearly, the model should be tested for conditions representative of the target population.

For specific context projects, evaluation constitutes an important part of the project. The CTIFL and SeptoLIS projects involve several years of multi-site testing, where model results are compared to field data. The data can be considered representative of the target population. Furthermore, in both cases the models are tested against new data, and so it is indeed predictive quality that is being evaluated. The Ventilation model was already tested by the original developers, but will be tested under French conditions.

Evaluating representative context models is in general more difficult. The model needs to be tested for a wide range of management decisions, some of which are quite different than current standard management. It can be very difficult or essentially impossible to obtain experimental data that is representative of the full range of management, and also the range of

climates, soils or animals of interest. A common practice here is to base evaluation on past data, often collected for other purposes, even if this is not exactly a representative sample of the conditions of interest (example: Winter Rape, Azosystem, ALOMYSYS and Genesys projects). Three of the projects in our sample involve a particularly large range of management options (MELODIE, SIPPOM and GENESYS projects) and, in these cases, it is essentially impossible to obtain data representing the range of decisions of interest. At best, one can evaluate separately specific parts of the overall model.
Rather than basing evaluation purely on data, another possibility is to ask experts to evaluate a model. In the MELODIE project, experts evaluated the decision part of the model. The ATEC model is regularly evaluated by field technicians and farmers.

Provide documentation

During the project, documentation of various sorts is produced. The specific context projects generally produce a user manual and information about the model (CTIFL projects). Some of the CTIFL projects also include a tutorial.
The representative context projects generally produce publications in the scientific literature, but may also include a user manual (MELODIE) and separate documentation about the model (ALOMYSYS, GENESYS).

Deliver software

The specific context projects have a clear end point which is when the software is made available. In many cases, this involves adding the model to a modeling platform, and thereby making it available as a web application. Note however that in general some further model evaluation, maintenance and evolution occur after that time.
The end point of representative context projects is less clear cut. In general there is not a single point at which one decides that the software tool is now finished and can be used for scenario analysis. Rather, at some point scenario analysis begins but the evolution of the software tool continues.

Discussion

In the specific context projects the major objective is to create a software tool for a wide audience, which may include farmers, extension personnel or other professionals. It may be the model itself that is made available to users, or the results of the model. In either case, the tool is meant to provide information about specific situations, for example a specific climate sequence, or a specific climate and soil, since each user will use the tool to obtain information applicable to his/her specific case. The model is thus meant to be run many times, each time for a new context.
In the representative context projects on the other hand, the major objective is to create a software tool that can be used to explore a range of management strategies, for a relatively small number of contexts. The tool is destined, at least initially, for a small group of researchers or engineers directly involved in the project. The model may be run many times, but in general it is only specific aspects of the context, in particular management decisions, that are varied. For the fixed parts of the context, usually only a small number of possibilities is studied.

The differences in objective and in targeted users between specific context and representative context projects have repercussions for almost all aspects of the projects. Firstly, the two types of project differ substantially in the extent of the systems that are modeled. In general specific context projects involve relatively simple systems, which are amenable to simple decision aides. Representative context projects in general concern more complex systems, because one wants to take into account explicitly the interactions between several aspects of the overall system.

Secondly, the software developed in the two types of project is quite different. Since the specific context projects aim at a large body of users, the ergonomy of the tool is very important. This includes not only the user interface for running the model, but also input of data for driving the model. Even if it is the results of the model that are furnished to users, rather than the model itself, it is still necessary to run the model often with new input data, so ease of use and automatic updates of weather are still important. To reduce programming effort, modeling software platforms are used for multiple models.

The software requirements for representative context projects are quite different. Considerations of ease of use are secondary, so the computer effort is not in general concentrated on this aspect. The models are in general more complex than for specific context projects, and therefore much of the effort is devoted simply to getting a working model. Representative context models are often based on combining several more basic models. This suggests that it might be very useful to have a platform specifically adapted to representative context models, where the building blocks (modules) could be stored and easily reused. Such platforms exist (Hillyer *et al.*, 2003; Chabrier *et al.*, 2007; Jones *et al.*, 2003). Use of the RECORD platform, (Chabrier *et al.*, 2007) is slowly becoming more widespread in INRA.

Model evaluation takes quite different forms in the two types of project. In the specific context projects model evaluation is often the major part of the project. The models are generally tested for several years before being offered to the public and then performance is monitored each year. The evaluation involves testing the model for a range of situations representative of those situations where the model will be used.

Model evaluation is in general much more difficult for representative context models. These models concern a range of alternative practices in place of standard practices. Thus one needs not only to sample from environmental conditions but also to test a range of practices. In general, one tests the model with available past data rather than trying to obtain a representative sample of conditions of interest. It is particularly difficult to evaluate models that take into account the spatial organization of cropping systems, since the number of combinations of interest is very large, while obtaining data is difficult because each test involves multiple fields. It is also very difficult to evaluate a model that treats the different activities on a farm with both animals and crops, since again the number of management decisions to test is very large and each test involves a whole farm.

An important question is the frontier between the two types of project. Couldn't one use a model developed in a representative context project for decision support? In principle, it would simply be necessary to input the specific data for each new context, rather than using data for a few representative contexts. Other than that, the model could remain the same. In fact, some of the representative context projects here specifically state that the ultimate goal is software for farmers or agricultural professionals. On the other hand, there have been several reports that the adoption for decision support of crop model based tools, like those in the

representative context projects here, is often poor (McCown *et al.* 2002, Stephens & Middleton, 2002).
It is clear that the transition from assessment to decision support can occur. In fact, many of the models in the specific context projects here are closely based on models in the literature, which were developed in representative context projects. However, our analysis suggests that it is not simply a case of taking a model developed for assessment and offering it to a wider audience as a decision tool. Rather, developing a decision support tool should be considered as a new project.
Our survey brings out some of the reasons why a new project is required. The first concerns the objectives of the project. In general one must carefully analyze the real needs of the target users of the new project, and this may lead to a specific context project with somewhat different objectives than the precursor representative context project.
Another difficulty concerns the software. In specific context projects the ergonomic aspects of the software are very important. Of particular importance is simplifying access to the necessary input data for the models. This may require software quite different than that developed in a representative context project. A standardized description of a farm and its operations would obviously be very helpful here, since then various different tools could be designed to use the same data. This subject is under discussion in France (Waksman *et al.*, 2010).
Finally, for specific context projects, model evaluation is a major point to provide a useful tool to the agricultural profession.

Conclusions

This paper describes how modeling projects for agricultural development are carried out, based on a survey of 20 projects in France. The projects include models aimed at disease or pest control, crop management, herd management, management of mixed grazing systems, or choice of animal housing.
The emphasis here is not on the models themselves, but rather on the overall project which begins with a definition of the objectives and ends with the software being made available for its intended use. We do not attempt to describe an ideal project, but rather to describe how actual projects have been or are being carried out. This study should be helpful for other projects, as a basis for comparison or to help in project planning and execution. The survey clearly shows that developing a model is a major undertaking both in terms of time (usually several years) and human resources (usually several participants with different skills). It is thus important to provide information that can help organize and carry out these projects.
Despite the diversity of the projects considered, the stages and activities of the projects are quite similar among the different examples. However, the way those activities is carried out is quite different. A major conclusion here is that there is quite a sharp distinction between two different kinds of project; those aiming at software for decision support, to be used by farmers or counselors (termed here “specific context” projects), and those aiming at software for assessment of agricultural production systems, to be used by a small group of researchers or engineers (termed here “representative context” projects). The former tend to treat less complex systems, make more use of existing models, use modeling platforms to limit the effort required for software development, and expend more effort on model evaluation. Given the

differences throughout the project, it is important then to clearly identify the type of project from the beginning to avoid a potential source of failing.
For new projects in the agronomy context, because of the difficulty to gather sufficient resources and all the required different skills, the best advice to stakeholders is certainly to take time to consult potential users and to well define a shared objective. Thus, it will be easier to focus efforts on demanding stage according to the type of project, “specific context” or “representative context”, they will have decided to conduct.

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