A Knowledge Management System for Exchanging and Creating Knowledge in Organic Farming

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Abstract: Agriculture must evolve into a more environmentally-friendly approach while remaining economically workable. This type of agriculture is said to be sustainable. It has a systemic logic and therefore requires a strong knowledge base. In this study we propose a knowledge management IT-based system. In the first part of our article, we discuss the potential actors of the system and their possible implications. The second part deals with the knowledge selection and formalization. The third part describes the main computing features of the knowledge server we propose.

Keywords: sustainable agriculture, organic farming, knowledge management system for agriculture knowledge modeling

1. Introduction

Agriculture is involved in a vast societal movement, linked to the framework and the values associated with sustainable development. To make a success of this transformation, agriculture will have to become both integrated into its environment, and organic (Butault, et al., 2010). This transformation depends largely on the mobilization of knowledge and know-how. But in 2011, while numerous professional software packages are accessible to farmers, no structured, interactive IT tool for knowledge management is available to them. We thus suggest developing a knowledge management tool dedicated to farmers. Its name is KOFIS "Knowledge for Organic Farming and its Innovation System". In the first part of our article, we study who the actors of KOFIS are, and their possible implications. The second part deals with the contents of the tool and the selection and formalization of the knowledge. The third part describes the main computing features of the knowledge server we propose.

2. The knowledge actors

2.1 Farmers and agricultural advisers

Within the framework of an investigation of both conventional and sustainable farmers, we distinguished for each type the various available information sources for the protection of crops. Figure 1 summarizes these main flows, their nature as well as their origin. In conventional agriculture, information exchanges are important, in particular from cooperatives and trading activities. In sustainable agriculture, in addition, the appropriation of knowledge by the farmers is fundamental, even if knowledge management is also present in conventional agriculture (Compagnone, et al., 2008). This is achieved, for the most part, by exchanges between farmers and, in the best configuration, by the presence of an expert advisor.

(Darré, 1999) showed that the farmers are very often organized into Local Professional Groups (LPG). Depending on the circumstances, these are more or less structured within existing entities. The makeup of the LPG is associated with the geographical proximity of the farmers but also with similar agricultural practices. Each brings his immaterial resources, built from his experiences or stemming from his own networks (Mathieu, Lasseur, & Darré, 2004). This shared knowledge is either then transformed or rejected.

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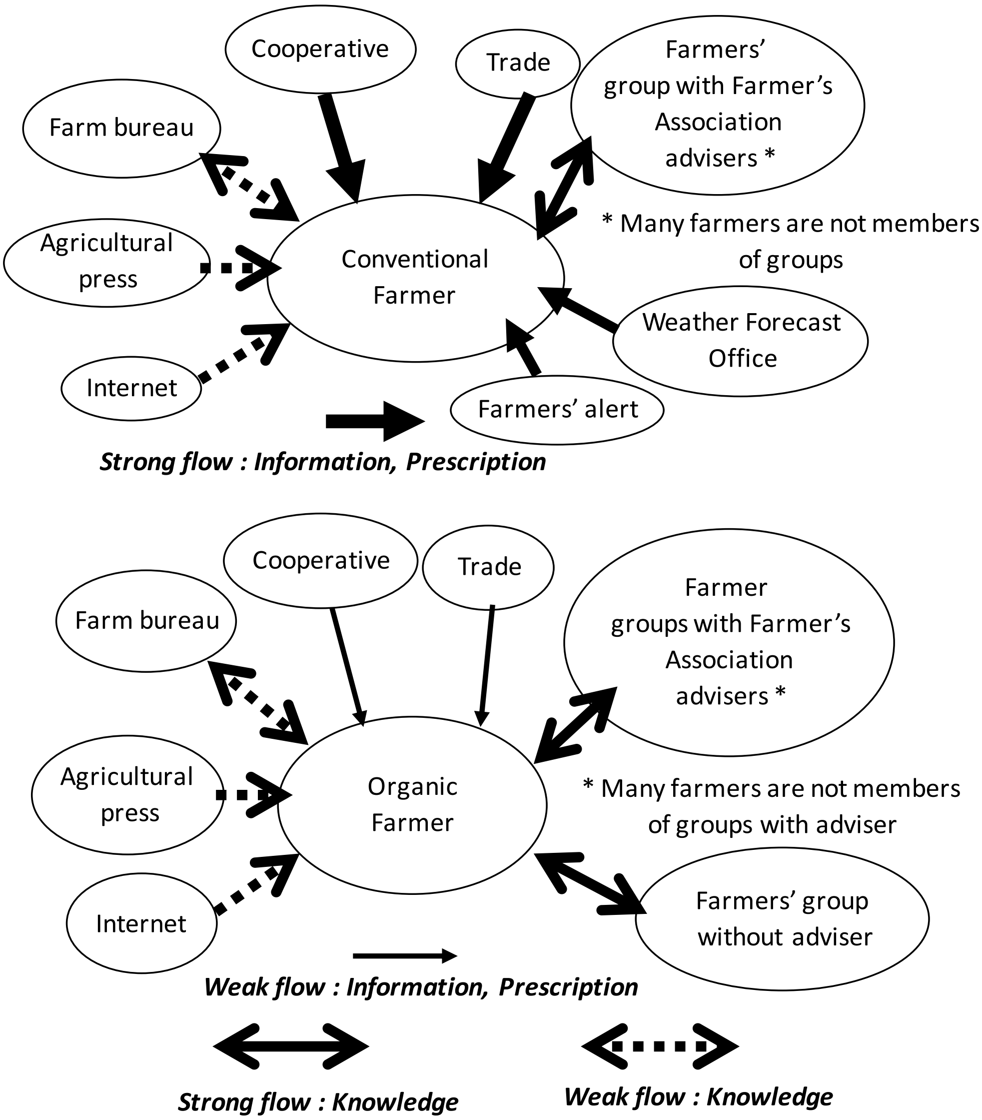

Figure 1: Main actors of the management of the knowledge in direct contact with farmers: sustainable vs. conventional

2.2 The dynamics of exchanges between the actors of the "agricultural knowledge system"

The concept of "agricultural knowledge system" groups, bringing together all the institutions, advisers, education and research involved in the construction of a sustainable agriculture (Marianne Cerf, et al., 2000), underlines the interest of the production and acquisition of knowledge within the framework of a partnership between the actors of the general agricultural world. In terms of interaction, an internet-accessible tool facilitates new relations. These are presented in Table 1 below.

Table 1: Types of interactions to be strengthened between actors in sustainable agriculture

Actor To From	"Sustainable" farmer	Farmers' adviser	Agricultural teacher	Researcher
"Sustainable" farmer	Non-local farmers or those not practicing the same type of sustainable farming	Advisers who do not follow the farmer or do not participate in in-service training as trainers	All agricultural teachers (except partnership with farmers or participation in in-service training)	All researchers

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Actor To From	"Sustainable" farmer	Farmers' adviser	Agricultural teacher	Researcher
Farmers 'adviser	Farmers not followed by the adviser or who do not participate in his in-service training	Agricultural advisers who are not of the same region and who are not members of the same advice networks	All agricultural teachers except partnerships with an agricultural school	Researchers who are not members of the same networks as the agricultural adviser
Agricultural teacher	All farmers not associated with agricultural schools or who do not participate in their in-service training	All agricultural advisers not associated with agricultural schools	Agricultural teachers between disciplines or between teaching establishments	All researchers
Researcher	All farmers	Agricultural advisers who are not members of the same networks as the researcher	All agricultural teachers	Interactions already exist within the framework of publications and conferences

2.3 Role of the actors in the system

Not all the actors have the same importance. Thus, buying groups often enter into contractual relations with the farmers through cooperatives or trading. On the other hand, research organizations and the agricultural adviser often have no obligatory relations with the farmers. In these conditions, will all the actors in direct or indirect relation with the farmers have an equal access to this knowledge management tool? If the answer is negative, on what basis can the roles of the actors of the tool be distributed? The development of a collaborative knowledge space relies on a capacity to appropriate the experience of others. The actors also have to share the same objectives. The approach of a technical salesman to an organic cooperative is to sell his products and buy the crops produced. His participation in a knowledge management tool is thus inevitably influenced by his interests. However, it is possible to distinguish the users of the site who will potentially have read/write access (the farmers, the participants in the "agricultural knowledge system") from those who will have read-only access (cooperatives, traders, local authorities), c.f. Figure 2.

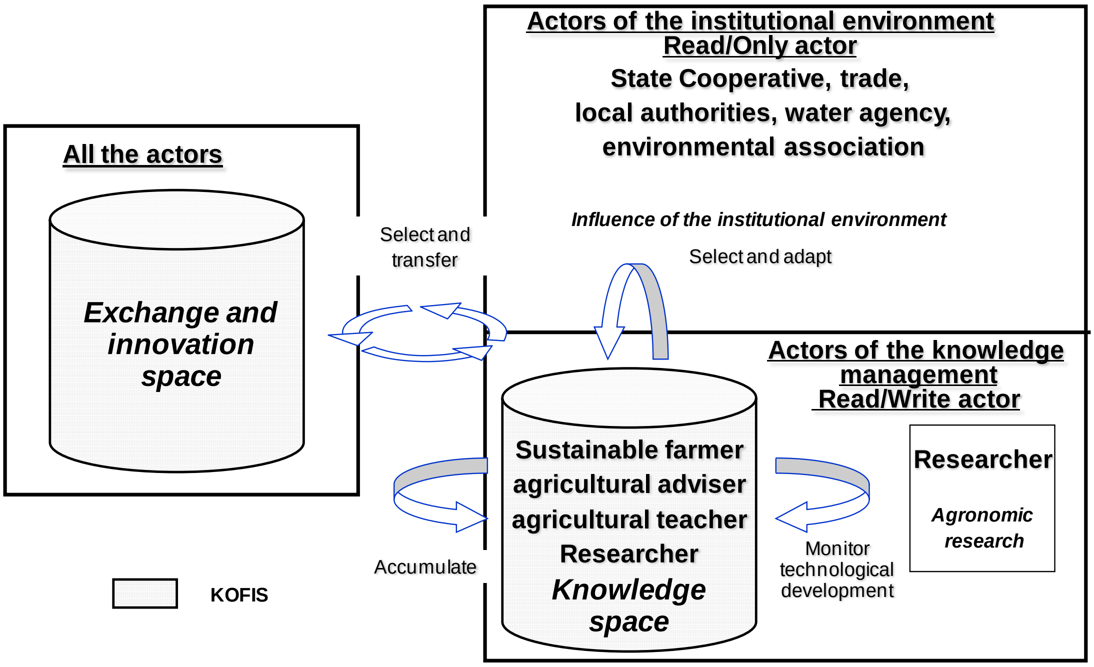

Figure 2: Role of the actors in KOFIS according to (Jean-Louis Ermine, 2007a)

In the read/write actors' space, we separated the farmers from the researchers, considering their communication difficulties. There is however no question of restraining innovation by separating researchers from the other development actors (Le Masson, Weil, & Hatchuel, 2006). Agricultural advisers or agricultural teachers can monitor and transfer academic knowledge stemming from research.

3. The knowledge capital

In the approach we propose, we will privilege organic farming. Its main advantage is that it has a recognized label. The institutional environment is relatively well known (Enita de Bordeaux, 2003). This choice is not limiting, because the problems are similar between integrated agriculture and organic farming(Lamine, Meynard, Perrot, & Bellon, 2009),

3.1 Knowledge capital in large-scale organic farming

The description of the knowledge capital is made using the "Organization, Information, Decision, Knowledge" (OIDK) model. This model comprises four sub-parts: the decision system, the information system, the operating system and the knowledge capital (J-L Ermine, 1996, 2[ième] édition 2000).

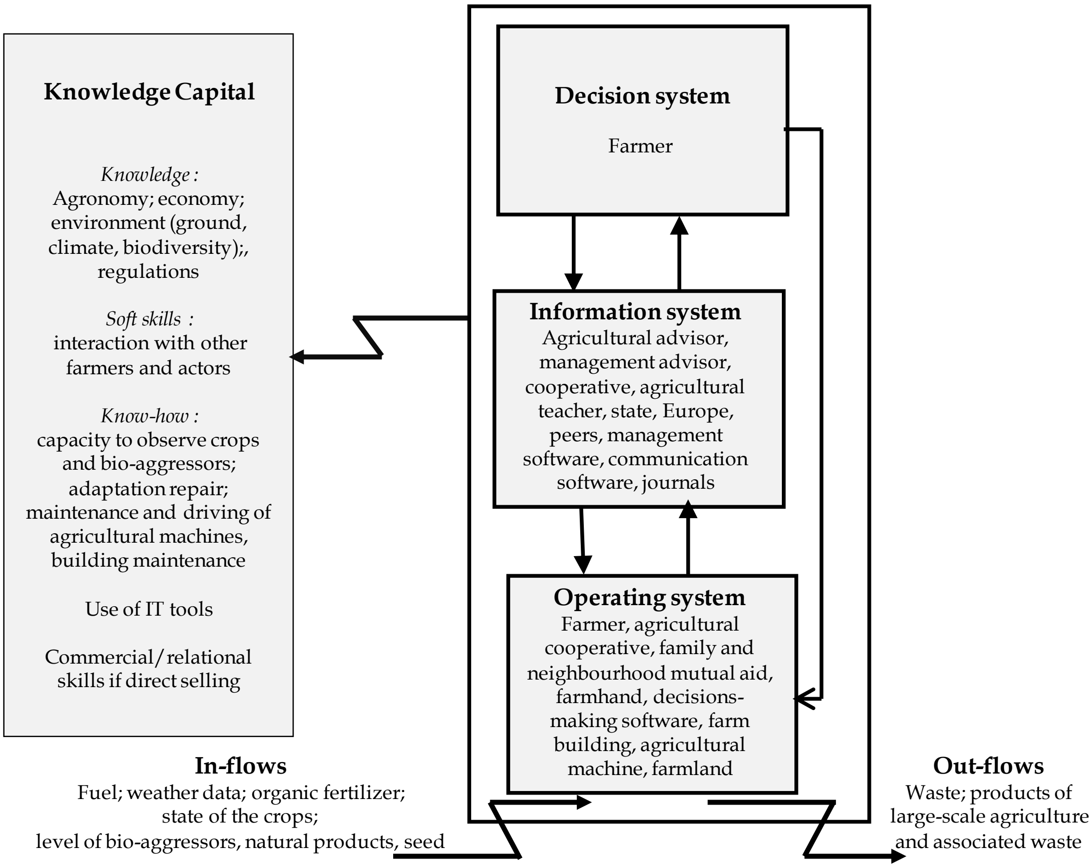

Figure 3: The OIDK model dedicated to large-scale organic farming.

In the figure above, we have positioned all the consumed and produced information in three systems: decision, information and operating. The knowledge capital aggregates the knowledge carried by these systems.

- **The decision system** includes the agents who pilot the system. According to the canonical decision model proposed by Herbert Simon, quoted in (Le Moigne, 1999), the decision process includes three phases: 1) An intelligence phase identifies and formulates the problems and connected risks. The problems are very often associated with a project and build up gradually. 2) If the solutions stemming from routines are ineffective, a design phase generates possible solutions and estimates them. 3) Finally, a multi-criterion selection phase retains the solution. On a farm, the farmer follows all these phases of the decision model. At the end, he retains a solution which is:
- *in compliance both with his own value system and that of his social environment (Darré, 2004b),*

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- *the most relevant in terms of efficiency with regard to one or more of his general objectives, associated with a projected program and with its corpus of decision rules (Sebillotte & Soler, 1988)*.

Let us not forget that a farm is a very small firm, and the farmer is financially and legally responsible.

- **The information system** includes the agents who inform the farmer. It comprises all the strategic and tactical information supplied by these actors, which become information consumed by the farmer. The information system also lists the information produced by the farm. This information fulfils one or more purposes (ACTA, 2007) i.e. the voluntary approach to organic farming, the regulations, but also the conditions concerning CAP (Common Agricultural Policy) aid. In spite of its importance in sustainable agriculture, recording rotation information is not compulsory with regard to the three purposes seen above. Suppliers' certificates (associated with the labels of seeds and plantations as well as with the invoices) monitor product traceability and allow the real production conditions to be certified. They also guarantee respect for the organic network. The keeping of a phytosanitary register is associated at the same time with the community statutory constraints of the hygiene package and the CAP aid conditions. The recording of other technical operations is on the other hand a voluntary act on the part of the farmer, who will frequently keep a trace of his operations in a "plains notebook ".
- **The operating system** connects actors and flows which generate the products. The farmer is mostly in the operation. He subcontracts some mechanical tasks to CUMA (Cooperative use of farm machines) or ETA (Contractor). Decision-making software optimizes the contributions of input products. These are less present in organic farming because there are fewer possible products and they are more complex to manipulate.
- **The knowledge capital** lists all the knowledge used and brought by all the actors and by all the artifacts listed in the operating, information and decision systems respectively. In the case of knowledge management in agriculture, it is difficult to separate the contents of the initial training from the knowledge acquired during professional life. Indeed, the agricultural high schools have constant relations with the professional environment. They are moreover under the direct supervision of the Ministry of Agriculture, contrary to all other educational establishments, which depend on the Ministry of Education. They participate in initial training as much as in vocational training. We thus suggest enriching the heritage model of knowledge legacy model proposed by (J-L Ermine, 1996, 2ième édition 2000) by distinguishing initial knowledge from knowledge acquired during professional life. Some knowledge acquired in initial training is regularly updated, if only by practice or life-long learning. On the contrary, some knowledge is acquired for the main part on the ground, such as a sense of observation of bio aggressors.

3.2 The essential contents of the knowledge management tool

The complexity of designing a sustainable culture system explains that knowledge cannot be proposed to the farmers in the form of complete and general decision-making models (Osty, 1990) However, the mere presentation of monographs associated with each farm is neither sufficient nor relevant. There is indeed a regularity of knowledge which goes beyond the farm. On the contrary, because of the variability of pedoclimatic conditions in agricultural production, numerous knowledge elements cannot be generalized on a large scale. Knowledge is dependent on the context. We try to obtain cognitive representations of the critical knowledge for the action in particular to design successful and sustainable agriculture systems in their context. We distinguish two types of available cognitive resources:

- The **thematic knowledge** is agronomic, economic or environmental knowledge. It has a general impact on all farms. It applies only partly to any given farm. On the scale of a farm, the most successful and most generic of these agricultural systems could be modeled and stored in a library, according to the idea of (Meynard, 2008). "Data, information, knowledge" modeling (Reix, 2004) is effective to describe cognitive processes in industrial production. It is conceptually limited to describe the cognitive resources necessary for agricultural production. The “reference” notion introduces a cognitive concept specific to agriculture. Thus, (Bortzmeyer, et al., 2011) suggest defining the reference as information which "is mobilizable, in order to act; clarifies (by opposition to tacit knowledge); exogenous (built by a third party); and context-dependent (the domain of validity is well-identified)". A reference thus holds at the same time some agricultural advice (thus information) and some localized knowledge (thus knowledge) enabling data to be interpreted.

References which illustrate the theoretical functioning of a farm could feed the library, as a typical case or a concrete case.

- *A **typical case** is a "fictitious farm, established by modeling, and described thanks to the concrete and coherent data of the farms studied by the same system". The typical case is cognitively effective, to pass on to operational actors knowledge which is tried and tested in a given environment.*
- *A **concrete case** is "a typical case studied because of the innovative character of certain of its points, but whose representativeness is generally minor over the territory of the department or the region". It is elaborated according to the same methodology as the typical case. The major interest of this concrete case is that it can supply suggestions for orientations, strategies and adaptations of the main operating systems of the department or the region (Chambre régionale d'agriculture de Bourgogne, 2009).*
- Other types of **contextual knowledge** are possible as a monograph. A monograph is the representation of a real farm, which can serve as reservoir of ideas to combine and test in different environments.

3.3 Critical knowledge

Critical knowledge is (Grundstein, 2002) that knowledge without which the crucial problems of an organization have no solution. This knowledge can be explicit or tacit. The measure of this criticality is founded on both the vulnerability of the knowledge (rarity, accessibility, cost and deadlines of acquisition) and its importance in terms of collective stakes. (Aubertin, 2007; Ricciardi, De Oliveira Barroso, & Ermine, 2007) are close to this mode of evaluation. (Aubertin, 2007) quotes in addition the difficulty of using the knowledge. All propose a grade system established by experienced users in the domain. (Viola & Morin, 2007) indicate a flaw in the construction of this criticality: respondents are tempted to overestimate the criticality of the knowledge which they manage directly. The question of distributed critical knowledge is also posed within the framework of the extended enterprise (Boughzala, 2007b). We listed experts' views on the priority knowledge to be managed, and developed the methodology to establish this classification. Table 2 presents the knowledge themes to be handled, in decreasing order of priority for the farmers.

Table 2: Hierarchy of the critical knowledge in organic farming

Knowledge themes
Weed
Phosphated fertilization
Nitrogenous fertilization
Climate, Ground
Crop rotation
Market
Sulphurated fertilization
Harvest, storage
Potassium fertilization
Varieties
Slugs
Insects
Airborne diseases
Ground diseases

3.4 Choice of a representation model

Which models to retain for the representation of knowledge in sustainable agriculture? The tool to be built first is a computerized knowledge book. The proposed knowledge is dedicated to a particular business and is de facto complex. It is enriched by academic knowledge. The logical representation of the knowledge cannot be reduced to an encyclopedic-type approach. It is necessary to be able to connect different knowledge elements together, and hypertext links are not sufficient for this. We thus set up original formalisms which can describe the farmer's job. These graphic models aim to facilitate

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the cognitive processes. They enable access to deeper forms of knowledge such as texts, and possibly images or videos (Moity-Maïzi & Bouche, 2008). The latter contain more specifically tacit knowledge, such as, for example, the regulation of the chain harrow. Thus, these models structure the knowledge.

We studied three available types of representation: GIEA **(**"Gestion des Informations de l'Exploitation Agricole" (Management of Farm Information))., CEMAgriM (Abt, 2010) and MASK (J-L Ermine, 1996, 2[ième]édition 2000). We take as comparison criteria the following factors:

- The presence of a method which guarantees the rigor required in the collection of knowledge.
- The capacity to represent thematic knowledge, as well as the capacity to represent a farm through a typical case, a concrete case or a monograph, according to the approach retained in paragraph 3.2.
- The nature of the language to represent the models. Indeed, too heavy an investment in the appropriation of a language is in contradiction with a strong participation of the users in the tool.
- Modalities of vast knowledge; if all the knowledge is not represented, the critical knowledge described above must be, in the widest possible range of modalities.
- The ease of appropriation of the models by the user.

We shall retain the MASK method, both to represent the thematic knowledge and to represent agricultural processes. It is immediately capable of expressing the reasons associated with the knowledge and thus enabling the users to understand it. This understanding by the final user is indispensable for the appropriation of innovative solutions on the scale of a farm. Furthermore, the exclusive choice of MASK to standardize the representation of the knowledge avoids the user's having to learn two different methods.

MASK comes from knowledge engineering, supplies a set of models and it based on the "macroscope of knowledge". The macroscope expresses the complexity of the knowledge. It is based on two hypotheses. The first is "semiotic": knowledge is information which has a sense according to a certain context. The sense and the context illustrate respectively a cognitive and an operational dimension of the knowledge. The second hypothesis is "systematic": knowledge is perceived according to three points of view: structure, function and evolution. This combination of both hypotheses is schematized in figure 4.

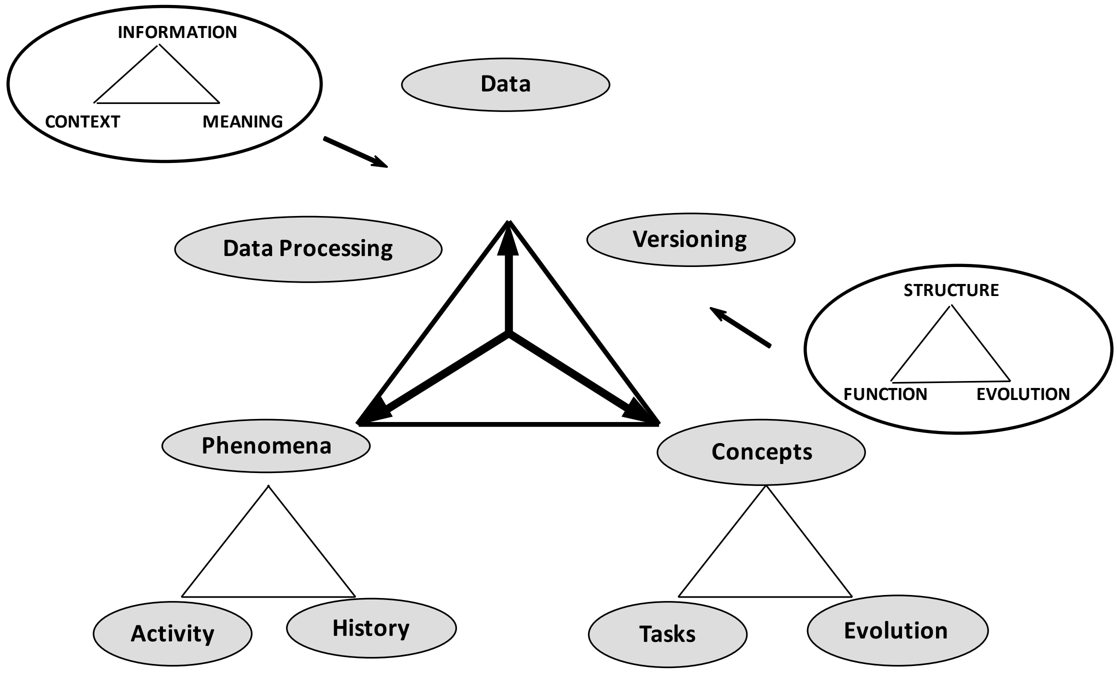

Figure 4: Knowledge overview (J-L Ermine, 1996, 2[ième]édition 2000)

It gives rise to 9 model types:

- Three models for the information: data, treatments and dating. So information is structured by the data, its function is to be treated and it is dated.
- Three models for the sense: concepts, tasks and evolution trees (lineages). The sense is constituted by the semantic networks of the concepts to which we apply cognitive tasks. The model of evolution is attached to the evolution of objects or concepts.
- Three models for the context: phenomena, activity and history. A context is based on phenomena which are the object of activities. The model of the history explains the historical context for the evolution of the knowledge over time.

These are necessary in theory to describe the knowledge. In most cases, two to three types of models are sufficient.

3.5 The MASK models applied to the organic farming

3.5.1 Models for thematic knowledge management

We applied this method to the practices of large-scale organic farms in the regions of Auvergne and Bourgogne. The profession recognizes the excellent skills of the chosen farmers. The rigor applied to their choice respects the MASK methodology. Indeed, it requires that the respondents have a high level of expertise in their domain. We will present two types of models applied to running large-scale agriculture:

- **The concept model** classifies knowledge according to a mode close to that of our study. In the case of the agricultural mechanization model for organic wheat production, presented on Figure 5, the farmer will classify intuitively the types of machines according to the logic of the work to be performed in the different agricultural tasks. For ergonomic reasons, we will not present the whole model. Thus, an object with shadow links back to a sub-model. In an IT tool, this connection is made by a hypertext link. Each of the identified machines is so many points of entry towards index forms which detail them and toward images which represent them. In the same way, a concept model could classify weed according to their threat level, with links to the associated methods of combating them.

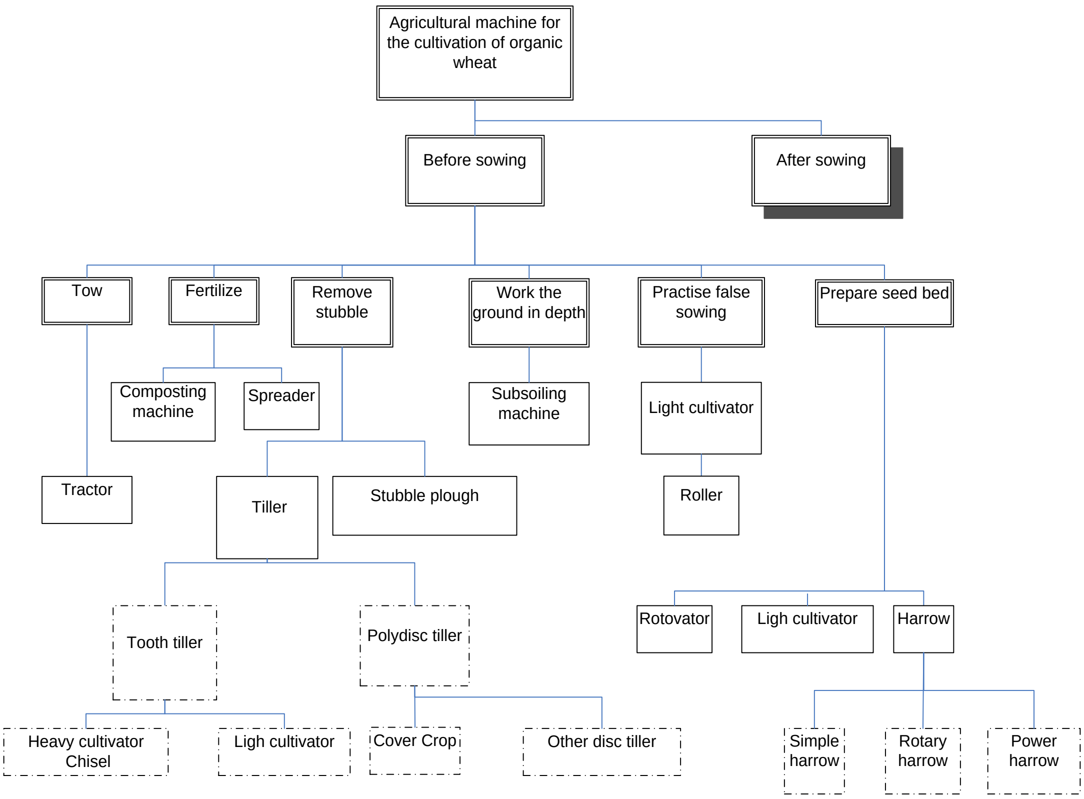

Figure 5: Concept model adapted to agricultural mechanization

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- **The task model** specifies the way a professional farmer reasons. He specifies his strategy to resolve a particular problem. To do this, he uses concepts already present in the concept model. Figure 6 shows the strategy for combating weed within the framework of growing wheat. It refers, for example, to the chain harrow, described in the agricultural machine model. An object with a shadow also links back to a sub-model.

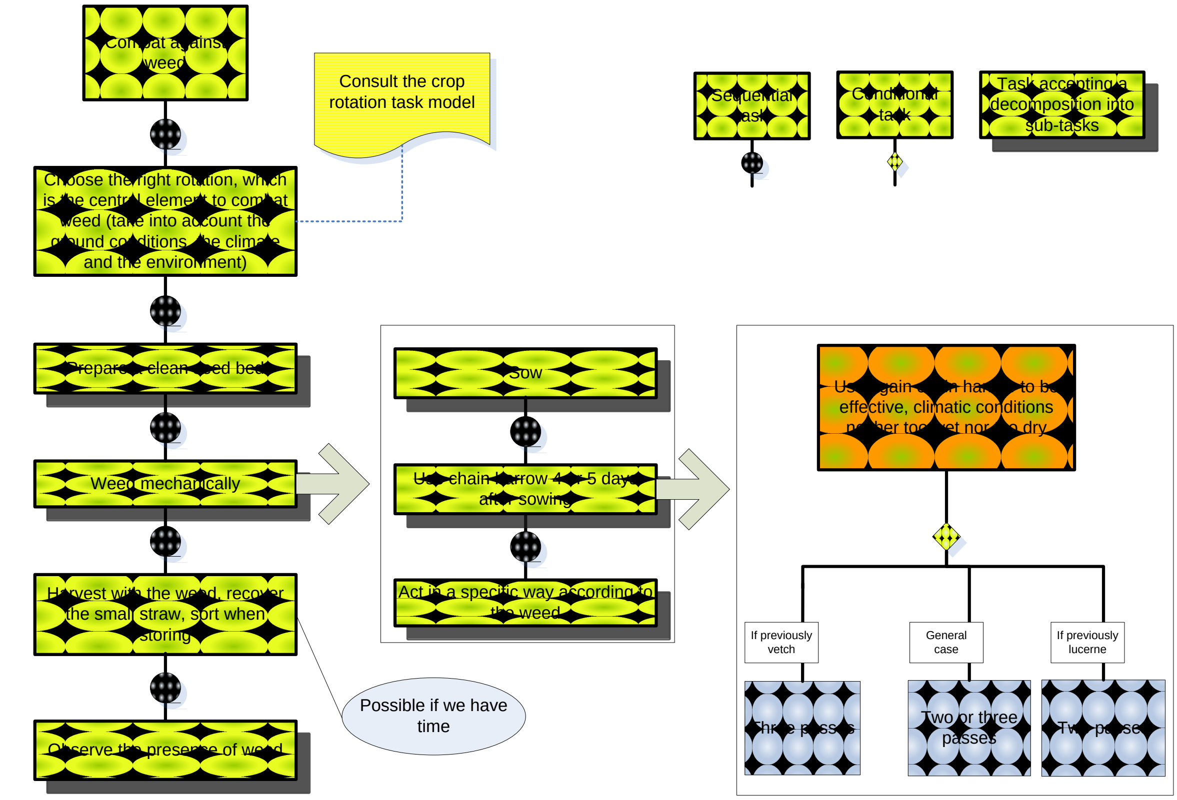

Figure 6: Task model of the strategy to combat weed

In spite of different climatic and environmental contexts, the bulk of knowledge is transferable from one region to another. On the other hand, depending on his own constraints, a farmer mobilizes only some knowledge. Thus, the models presented above supply farmers with knowledge that is not directly operational. However, they facilitate the organization of their agriculture systems, and associated technical processes, in the specific context of their farm. We presented about ten of these models to farmers. They quickly appropriated the associated knowledge.

3.5.2 Models to represent typical cases of innovative agriculture systems

We propose that the tool contains a library of innovative and sustainable agriculture systems in the form of typical cases or monographs. This representation requires several elements to be described: the domain of validity of the innovative agriculture system represented as well as its durability, the succession of crops and the technical processes with their decision rules. However, this pooling of information goes well beyond the representation of the results. The mode of calculation of the results and their validation must also be identified, published and even, in certain cases, homogenized. This homogenization is not simple to achieve in the divided landscape of reference tables produced by actors of diverse origins. By definition, the knowledge to be modeled is contextual. We will thus identify the models of the MASK method which are the most adapted to our objective.

- The domain of validity of the innovative agriculture system specifies the context of the typical case or the monograph which we wish to describe. The evaluation of the innovative system focuses its interest on criteria of durability. To express these parameters, the phenomenon model is used. It expresses well the idea of a global transition from one system to another one. Figure 7 presents the context of farms in Burgundy.

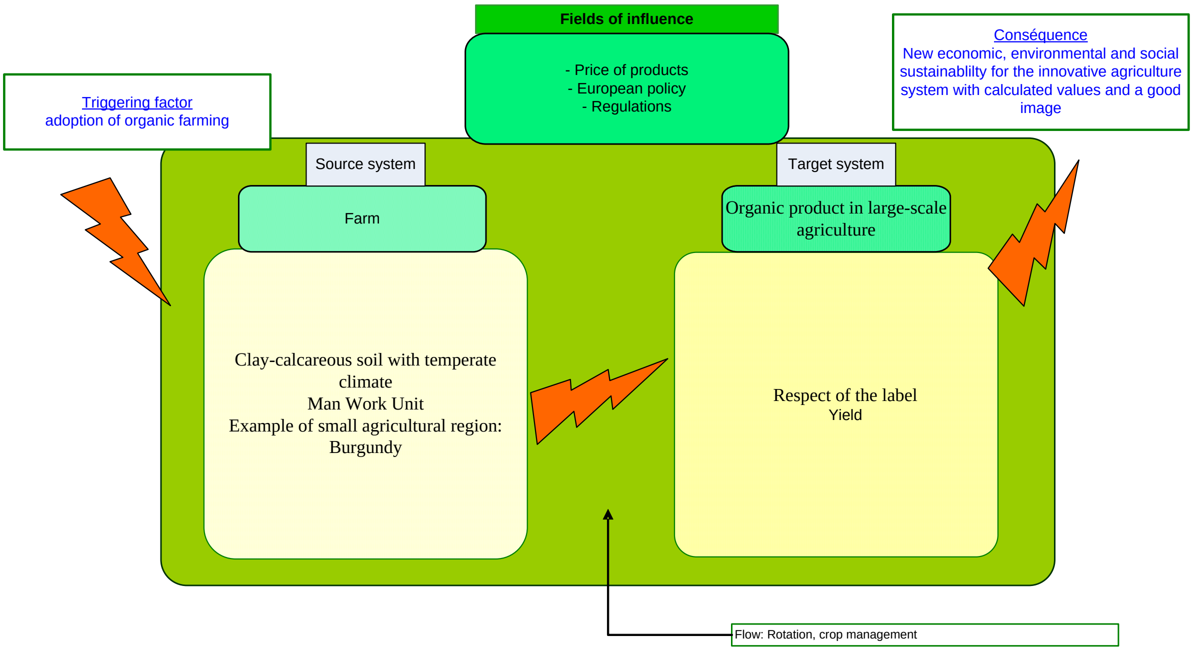

Figure 7: Phenomenon model of large-scale organic farming (in Burgundy)

- Crop rotation, as well as the technical sequences, is production processes associated with a plot of land. For the rotation, we briefly formalized the succession of crops (Figure 8). Every type of crop has a technical sequence, which is described by the activity model. Figure 9 above shows this for wheat production. Each stage of this process can be associated with one or more management rules. Every rule summarizes the reasoning of the farmer, associated with threshold values for the indicators. We suggest formalizing these rules using the task model above.

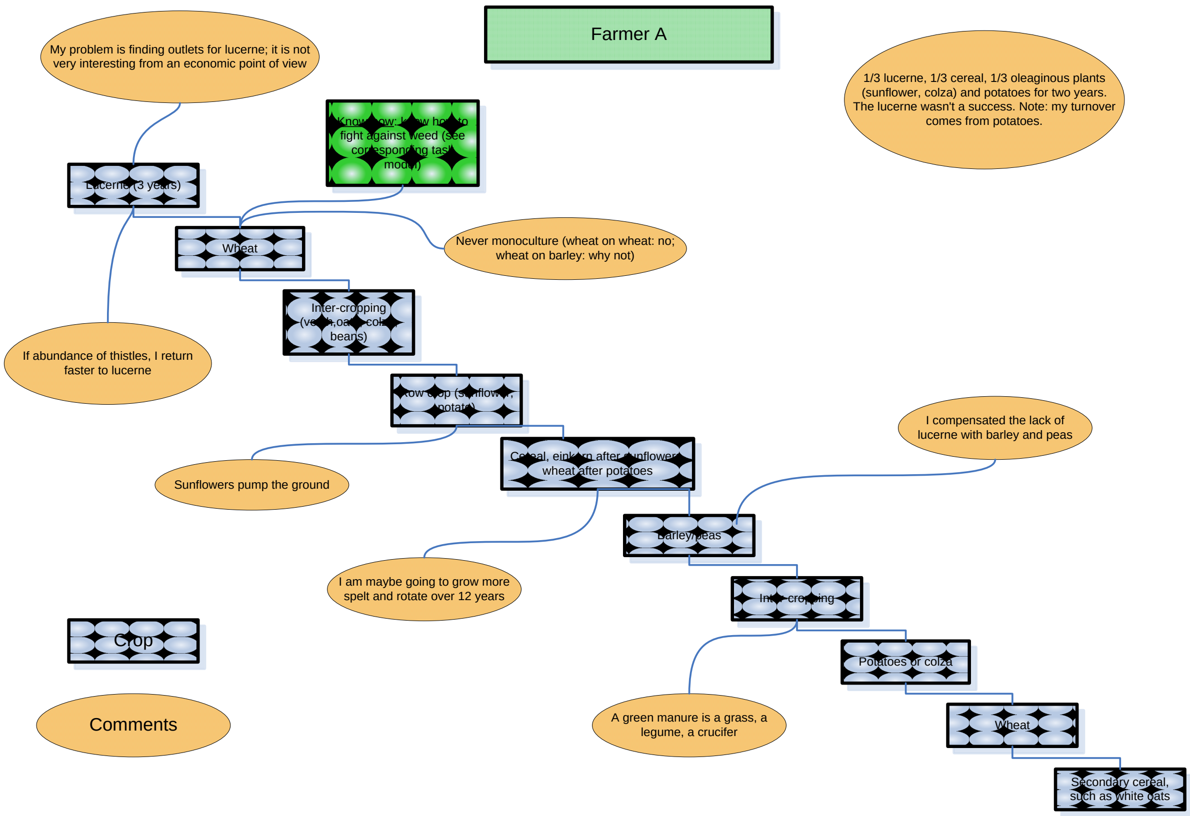

Figure 8: Description of a cultural succession

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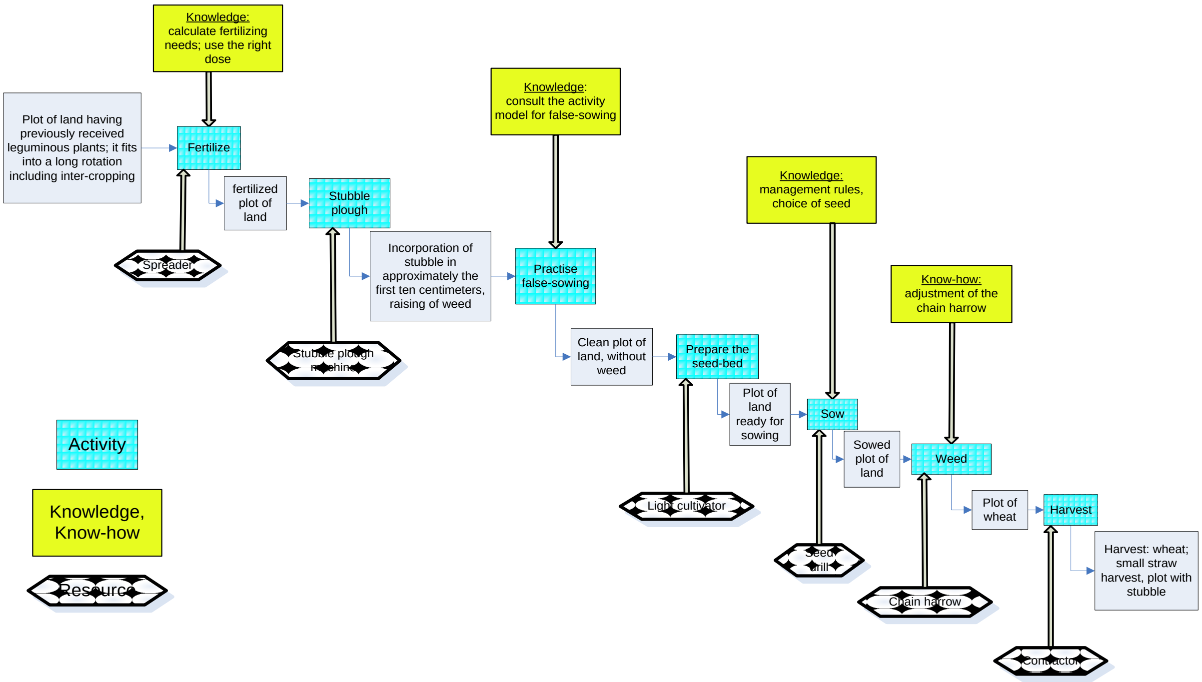

Figure 9: Activity model of the crop management for wheat

These various models best represent the directories of actions and the routine procedures (Mariane Cerf & Sebillotte, 1997) associated with the innovative agriculture system. They concern strategic choices (crop rotation), tactical choices (technical solutions or certain management rules) or operational choices (regulation of machines). The routine procedures, and in particular those connected to risk management, can be described through the task model. Figure 10 summarizes the place of the various contents in the knowledge tool which we propose in this article.

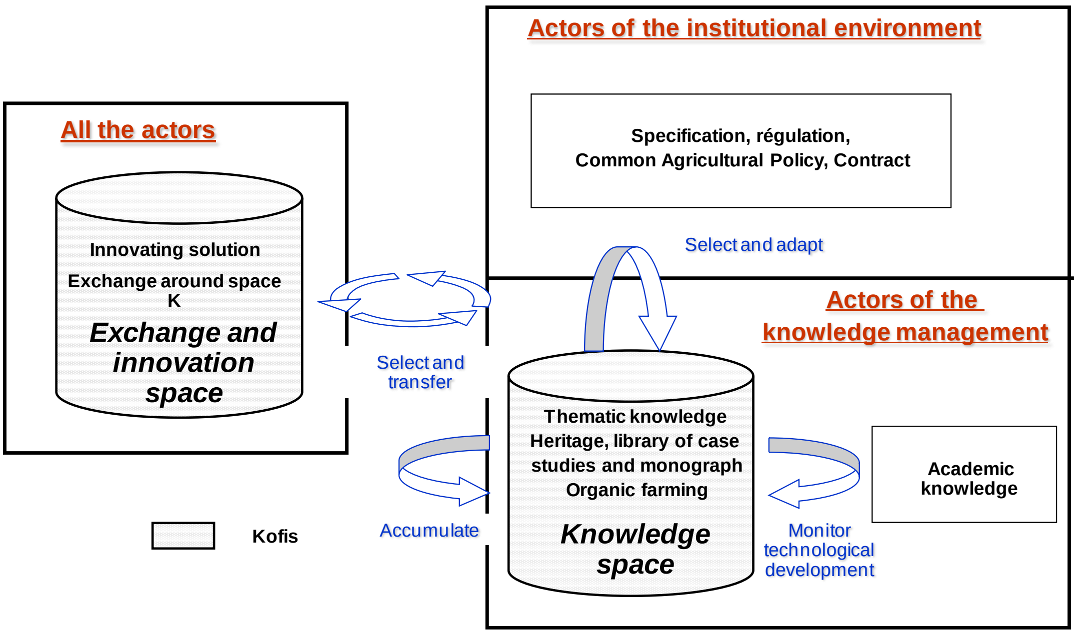

Figure 10: Contents of KOFIS.

4. The technological component

In the approach we propose, we will present the general specifications of KOFIS and then, based on a list of its properties, we will propose the detailed architecture.

4.1 KOFIS – general specifications

In the framework of two agricultural research projects, we have worked to complete and validate the general specifications of KOFIS. In the four following sections, we will describe successively what is globally required of the tool, the two technological responses deployed, and the functional requirements per user group. We will thus outline the main properties of KOFIS.

4.1.1 What are the general expectations for KOFIS?

KOFIS needs to be accessible to actors of different origins in various computing environments. KOFIS is thus a multi-actor web tool. In the first two sections, the analysis gives rise to two expression spaces with different logical approaches to the actors: a knowledge capitalization space [K] and an innovation space [I]. Thus, KOFIS stores operational knowledge objects in [K] and builds interactions in [I] to produce new knowledge.

Furthermore, the state of the art concerning the key success factors for knowledge management underlines the importance of the users' appropriation of the tool. KOFIS must be easy to use; for example, it should propose a WYSIWIG interface. This function allows the users/contributors to see immediately the final form of their contributions. The first property of the tool is its ergonomy.

Knowledge objects should be quick to access and intuitive. In addition, when faced with an unsolved problem, the system provides knowledge elements which facilitate the solution. Thus, with respect to these last two factors, the system should be designed to find rapidly explicit knowledge in the form of datasheets, images or videos. This function can operate via a word search in the file contents, for example. This method potentially provides numerous results, which are not always exploitable. It is necessary to go further by looking for technical solutions which enable more efficient and pertinent knowledge searches, including those in non-text resources.

In (Soulignac, Ermine, Paris, Devise, & Chanet, 2011) we also underlined the limits of an approach based on the geographical proximity of farmers to build their communities of practice. The system should therefore propose a different way of structuring and mobilizing these actors, who are repositories of tacit knowledge.

Two important functional requirements emerge. The first is concerned as much with knowledge capitalization as with problem-solving. The second concerns the question of the organization and structuring of explicit and tacit knowledge with a view to mobilizing it efficiently. We shall see how an adaptation of the C-K theory of (Hatchuel & Weil, 1999) and the use of a semantic web respond respectively to these two requirements.

4.1.2 Proposed responses: capitalization and innovation

The C-K design theory (Hatchuel & Weil, 1999) conceptualizes the innovation process, starting from knowledge capitalization. It distinguishes two spaces, one associated with tried and tested knowledge, the other devoted to innovation, and it reflects human reasoning when faced with a problem. In order to advance towards a solution, we build on the knowledge acquired from the different terms of the problem.

We propose to use a concrete problem to illustrate the different operations developed in the C-K diagram. The aim is to address the problem of aphids in a field of wheat, as illustrated in figure 11.

- K-C disjunction: this marks the beginning of the design reasoning process. A given problem – here the presence of aphids in a wheat field – is transformed into a concept: a wheat field without aphids. To initiate this reasoning, we base ourselves on relative knowledge to arable wheat farming. Pesticide products are used as little as possible; the aim is not to have to treat the aphids, i.e. to prevent their appearance. The "wheat field" object therefore has a non-logical property of "absence of aphids".
- Departition: if the initial concept has no apparent solution, departition mobilizes knowledge to establish as second concept which enables reasoning. Knowledge of different types of pest control in organic farming leads to a wider concept: the elimination of aphids in organic farming. Four types of control are mobilized.

- Partition comprises two operators: restrictive partition and expansive partition. Restrictive partition restrains the domain of possibilities. Thus, no machine is capable of efficiently removing aphids from wheat, so the mechanical control solution is eliminated. Expansive partition ensures the expansion of the innovation space. Properties are added to the concept. This process is creative, but these properties, to be credible, derive from knowledge. This is sometimes very far removed from the subject under discussion. Invention or surprise can then arise from reasoning. This process leads to one or more new proposals. In our example, knowledge of aphid auxiliaries makes two original proposals possible: one is the development of flowering perennials around reduced-size cultivated plots, and the second is the introduction of grass bands between the rows of wheat.

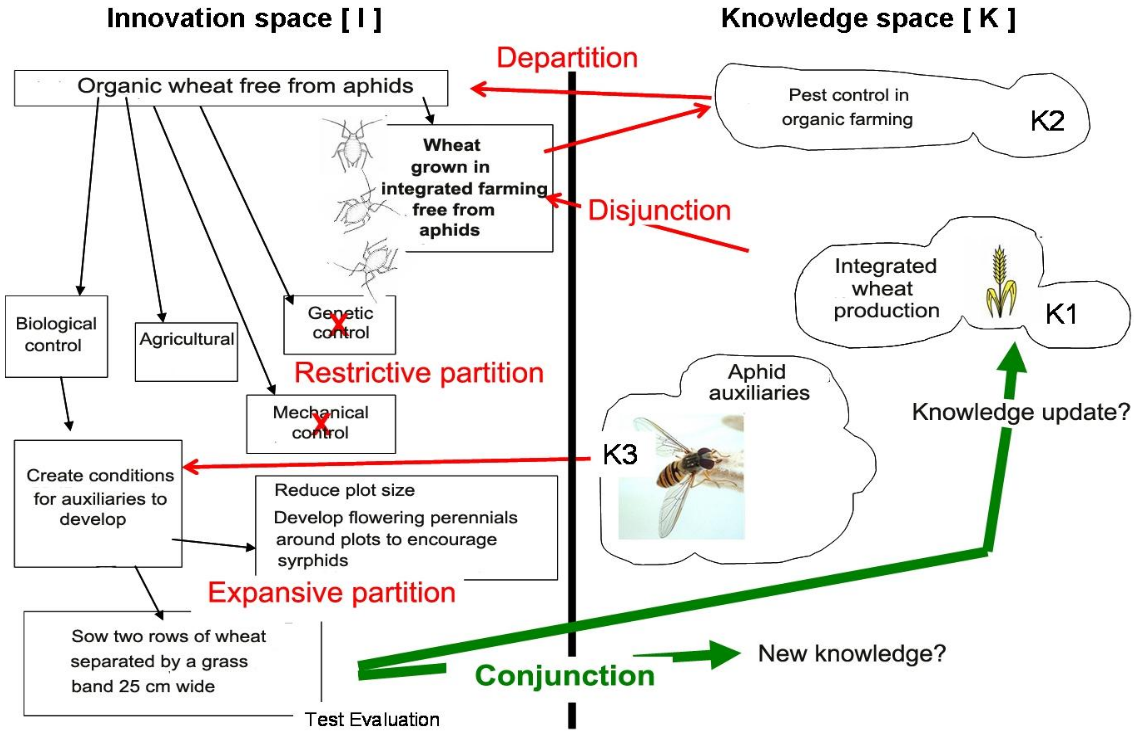

Figure 11: Example of the two spaces, [I]/[K]

- The C-K conjunction marks the end of the design reasoning process. If the final proposal is assessed positively, it acquires a logical status. It crosses over from the innovation space to the knowledge space. The last proposal becomes a knowledge item. Expansibility also applies to knowledge.

These four operations are not automatic; their implementation is human. But one of the merits of the C-K theory is that is specifies design reasoning in both [I] and [K] spaces. KOFIS must keep a trace of this reasoning in order to exploit its full potential. This proposal is in line with our analysis concerning the roles of the actors and the contents. Here we find the exchange and innovation space [I] and the knowledge space [K]. The search for solutions takes place in the [I] space, and the knowledge used to solve the problem belongs to the [K] space. When the problem is solved, the solution is validated as knowledge. KOFIS therefore has two web components: an exchange component [I] where the four C-K theory operators are to be found and a knowledge capitalization component ([K]. A second property of the tool is its capacity to maintain a trace of human design reasoning.

4.1.3 Proposed responses: structuring the knowledge

Most web tools do not impose constraints in managing their contents. Knowledge is hidden in HTML code, which is a data presentation language. The tags used by this language are used to organize the form of the data. Thus, the contents are hard to identify. With this type of language, only human intervention can retrieve and process knowledge. Now, there is an approach which structures the contents. One solution is to annotate the documents. Annotations link metadata to the resources, i.e. link data to the data in order to facilitate their identification. We will see below that there are two types of annotations. Social web-type annotations are based on tagging documents. A tag is a lexical marker which is associated with a resource. The search tool will thus retrieve all the resources (document, photo, video, etc.) associated with the selected tag. Tagging does not authorize a computer to infer anything about the resources.

However, the second type of annotations, associated with the semantic web, facilitates the use of knowledge by machines. The seminal article (Berners-Lee, Hendler, & Ora, 2001) described the principal computing elements necessary for the development of the semantic web. The semantic web initiative is supported by W3C, the international consortium which standardizes web technologies. It uses several layers. The semantic web increases content accessibility. Thus, in the example in figure 12, we compare two approaches when seeking a pest control method to fight against aphids in wheat farming: "Hypertext" and "Semantic Web". In hypertext modeling, the hypertext links enable an approach via non-intuitive steps. Links are static and their semantics are not specified. On the other hand, a semantic annotation, thanks to an inference process based on a semantic query, enables the computer to retrieve the correct knowledge element directly.

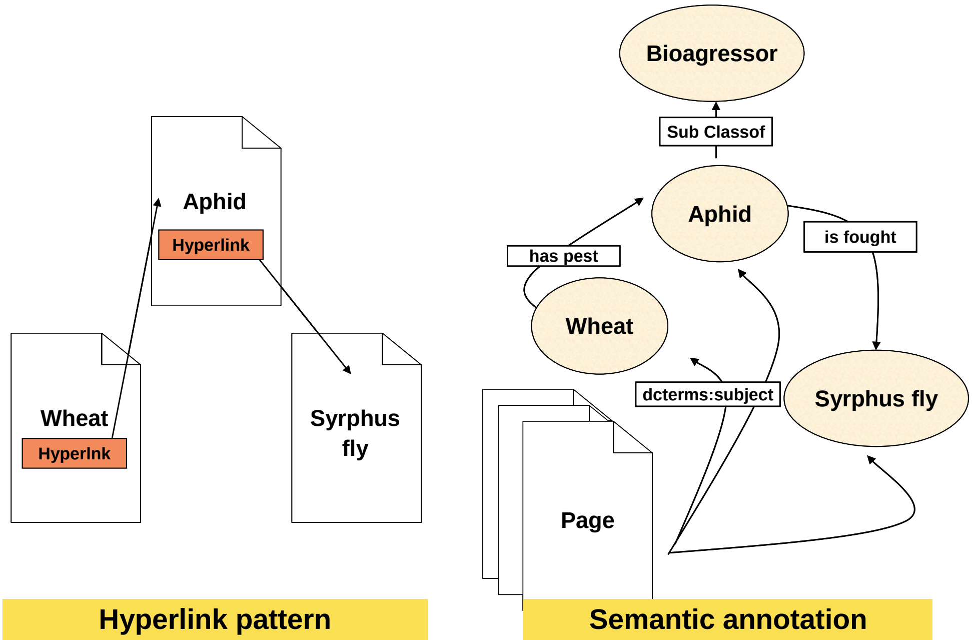

Figure 12: Hypertext and semantic web modeling

A document annotation system will therefore facilitate their retrieval, which constitutes the third property of KOFIS: the semantic dimension of the tool. We propose that the system should use the semantic content associated with the identification of each farmer, with a view to creating the most appropriate communities with respect to their centers of interest. Thus users find each other via profile matching. This capacity to construct a pertinent community is our fourth property. In order to facilitate the search for knowledge or knowledge owners, we need a tool which can structure this information. In conclusion, KOFIS has two web components, [I] and [K], and each of these spaces should provide a semantic annotation function for its users.

4.1.4 What are the functional requirements of each user group?

KOFIS is a collaborative tool. Its users have various different profiles (farmer, advisor, teacher, researcher…), they are geographically distant and they have access to heterogeneous computing resources. These actors share their experience and their knowledge by editing pages or posting comments. As regards the diversity of the actors, the difficulty is to find a balance between allowing the largest possible number of actors to publish in the tool and maintaining control of what is published. According to their status, the actors access the database contents with varying rights. Two types of actor have already been defined, in the paragraph concerning the organizational component, as the < institutional environment> and the <agricultural knowledge system> (see figure 2). Three other types of actor, the visitor, the moderator and the administrator, are also present in the system. Thus we find the five types of actor whose rights are present below in a hierarchical sequence. Each actor type inherits the rights of the preceding actor types.

To express the principal specifications, we will use two types of UML model: utilization types and activity diagram. Figure 13 illustrates the main functional uses by KOFIS actors type. Table 3

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indicates the distribution of these uses between the [I] and [K] spaces. The KOFIS <visitor> has free access; other users are authenticated by a classic login/password system. Apart from <visitors>, all users communicate identity information to the system, in order to inform the community's creation process later on. For example, a farmer will communicate information about his crops, whereas a researcher will indicate his fields of expertise. The ontology, once defined, is relatively stable; only the <moderator> may change it. This avoids the risk of multiple or redundant ontology, which is counter-productive. Indeed, a common, simple, shared vocabulary is necessary. Conversely, instances associated with the ontology will be enriched as the tool fills up. The actors of the <agricultural knowledge system> are responsible for maintaining a coherent arborescence for the innovative solutions. If necessary, they can re-organize these solutions. They also validate knowledge coming from this innovation space in order to publish it in the [K] space.

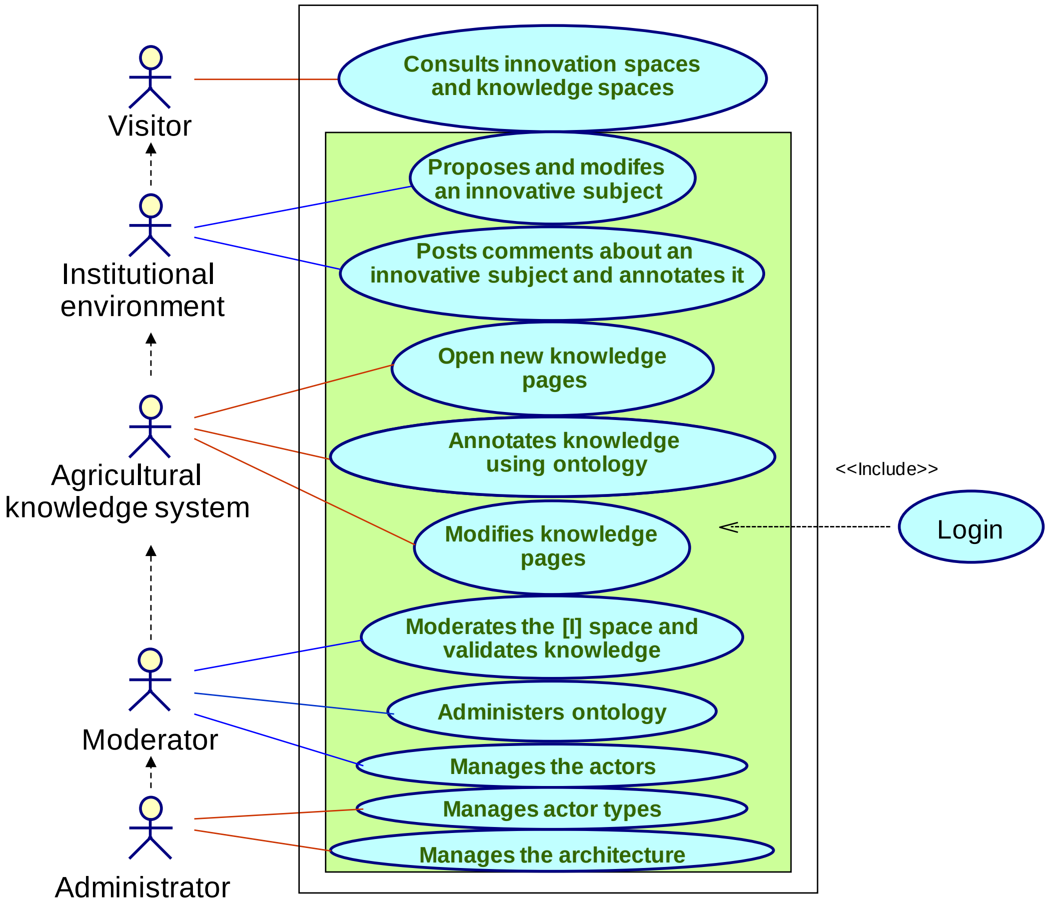

Figure 13: Principal KOFIS users

Table 3: Distribution of user types in [I] and [K].

<table>
<tr><th>Space type
User type</th><th>[I] Innovation</th><th>[K] Knowledge</th></tr>
<tr><td>Visitor</td><td>Read-only</td><td rowspan="2">Read-only</td></tr>
<tr><td>Institutional environment</td><td rowspan="2">Proposes and modifies innovative subject
Posts comments and annotations on innovative subject</td></tr>
<tr><td>Agricultural knowledge system</td><td>Opens, annotates and modifies new knowledge pages</td></tr>
<tr><td rowspan="2">Moderator</td><td>Moderates exchanges</td><td>Validates knowledge</td></tr>
<tr><td colspan="2">Administers ontology
Manages actors</td></tr>
<tr><td>Administrator</td><td colspan="2">Manages architecture
Manages actor types</td></tr>
</table>

The activity diagram in figure 14 shows the sequence of actions and decisions within an activity of a member of <agricultural knowledge system>. Let us describe the possibilities available to this type of

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actor. He looks for a knowledge item in [K] space. If it is present, he can enrich it, including semantically. When the knowledge item does not exist, he expresses his problem in [I] space and annotates this problem. Thanks to the semantic identifiers linked to each user, the system will propose a list of users who are pertinent for the actor of the <agricultural knowledge system>, who can complete the list. Thus, the subject will be processed, at least at first, by a community of users who have the required competencies. This avoids the passive forum approach, where users who are potentially interested in a question come across it more or less by chance. However, there is nothing to prevent a new user, not identified initially, to contribute by formulating an appropriate reply to the question posed.

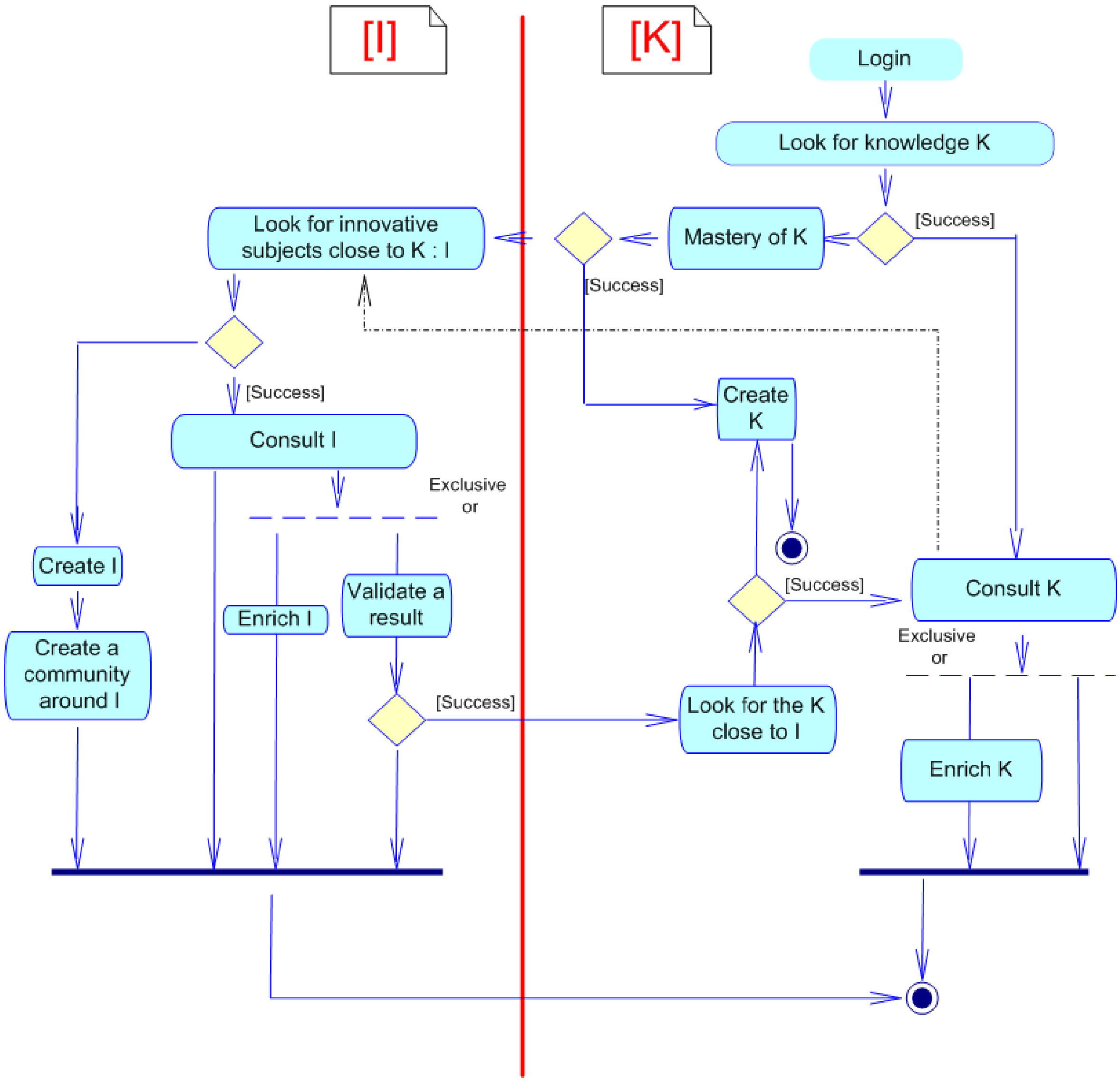

Figure 14: Main KOFIS activities for an actor of the agricultural knowledge management system

The analysis of functional requirements gives rise to a fifth and a sixth property:

- The fifth resides in KOFIS' capacity to generate different user types.
- The sixth is its approach to collaborative publishing and exchange.

We will add a seventh property, traceability: the capacity to conserve a trace of modifications, which enables a clean version to be reconstructed in the case of error or damage.

4.2 Architecture of the KOFIS tool

In the previous paragraph concerning the KOFIS tool's specifications, we identified seven main properties of the tool. They are summarized in table 4 below:

Table 4: KOFIS properties

Property	Description
1	Ergonomy
2	Trace the human reasoning associated with the design
3	Semantic annotation
4	Construction of a pertinent community
5	Differentiated management of user types
6	Collaborative publishing and exchange
7	Traceability

The tool functions due to the complementary dynamics of the collaborative spaces [I] and [K]. We need to develop or adapt one or two web tools to cover these two spaces and also to respect the properties identified above. Several solutions were studied to build the computing bases of the KOFIS web tool. First, we explored the software market (Balmisse, 2006) corresponding to our need for a collaborative and semantic knowledge management tool:

- CMS - Content Management System – is an IT application which designs the contents of a web site and manages its updates dynamically. It proposes several options for organizing content through blogs, forums, articles, “wiki” functions, etc. A CMS administers separately the contents and the form of a site. Many content management systems contain a WYSIWYG editor, and some features allow a more ergonomic organization with a tree structure of the contents. This tree diagram facilitates the representation of human reasoning. On the other hand, the functions of the semantic web are not yet fully developed, for example for blogs. The contents are stored in a database, which enables the management of concurrent accesses. A CMS manages the users and their rights.
- A wiki has a strong collaborative aspect for elaborating documents. Thus, unlike blogs, of which most only authorize users to comment on texts, the contents of the wiki are modifiable. This collaborative building leads to a rich knowledge base, the result of combining the knowledge and the experience of users/contributors in a particular domain. The wiki manages the traceability of the contributions. As for a CMS, some wikis include WYSIWYG editors. Unlike CMS, the contents of a wiki are not rigorously organized, with hypertext links being the main approach to page organization. Certain wikis can nevertheless be annotated. The wiki is also a storage mode in a database, as well has a system for managing users and their rights.
- The choice of several pertinent frameworks also enables the complete development of the application. In particular, Jena (http://incubator.apache.org/jena/) provides a framework for developing a semantic web application. Of course, in this framework all the expected functions are present, but with a considerable development effort. We compare the three possible options in table 5.

Table 5: Comparison of technical solutions

<table>
<tr><th>Tool / Properties</th><th>CMS</th><th>WIKI</th><th>Semantic Web solution</th></tr>
<tr><td>Ergonomy</td><td>Yes</td><td>No, in particular for discussion of knowledge pages</td><td>Yes</td></tr>
<tr><td>Traceability of the human reasoning associated with the design</td><td>Sometimes</td><td>No</td><td>Yes</td></tr>
<tr><td rowspan="2">Semantic annotation</td><td>Sometimes</td><td>Sometimes</td><td rowspan="2">Yes</td></tr>
<tr><td colspan="2">More advanced for Wiki than for CMS</td></tr>
<tr><td>Construction of a pertinent community</td><td>No</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Differentiated management of user types</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
</table>

Collaborative publishing and exchange	Wiki extension	Yes (all the site)	Yes
Tool / Properties	CMS	WIKI	Semantic Web solution
Traceability	No	Yes	Yes

To produce KOFIS, given the availability of "open source" tools, it is not necessary to opt for a fully-developed but costly semantic web solution. We therefore chose the following tools:

The innovation space [I] is devoted to collaborative reflection about a new subject. This aims to find a solution to an unsolved problem or to debate on existing knowledge. This space is accessible for all the actors of the agricultural world. To encourage the largest possible participation in this space, we seek simplicity. The publication system adopted should therefore be popular. We chose the CMS tool, because of its capacity to organize content and more particularly its publication features associated with blog entries. Unlike a forum, the blog part of a CMS enables knowledge capitalization while encouraging and organizing exchanges between actors. In addition, we chose a CMS type which has a tree classification mode. This will ensure the ergonomic display of the reasoning process which is specific to the innovation space [I]. A new subject will bring into play the development and exploration of several innovative solutions, each of which is associated with a blog entry. Each entry can be commented. For an unsolved question, all the explored innovative solutions are organized in a tree structure. The exploration of an innovative solution can be halted, and a new one can be proposed. This tree structure therefore generates restrictive and expansive partitions in the innovation space, which is conform to C-K theory. However, content management systems are less developed on the semantic level.

We could have retained the blog function of the CMS for the [K] space, since the more recent blogs contain functions close to those of wikis, particularly for directly building collaborative texts. However, their limitation is above all their lack of version history management. The other weak point is that their semantic quality is currently insufficiently developed. Due to its collaborative production capacity and its semantic dimension, we therefore chose the semantic wiki tool for the [K] space. The wiki system also includes discussion spaces, but does not propose ergonomic programs which can manage the interactions between actors on innovative subjects via a tree blog feature. In addition, the [I] space users are not the same as the [K] space users. In the innovation space, the community will be wider and more diversified, in order to search for new ideas and original experience results. However, it appears complicated to differentiate between the user profiles of these two communities in a wiki tool, typically very liberal in terms of rights management.

Given the general specifications of KOFIS, the analysis of the available IT tools leads to the choice of a combination of two types of tool: CMS for the [I] space and a wiki for the [K] space. They both also require a semantic dimension. For each of them, we sought the most pertinent “open source” software. For [I], we chose Drupal. For [K], we require a semantic wiki which combines the collaborative features of a wiki with the resources of the semantic web. We chose the SMW (Semantic MediaWiki) module (Völkel, Krötzsch, Vrandecic, Haller, & Studer, 2006).The IT architecture is presented in figure 15.

5. Conclusion

We showed that the use of MASK is satisfactory to produce a representative graphic language to pilot large-scale organic farming, for both thematic knowledge and case studies. They concern strategic choices (crop rotation), tactical choices (technical solutions or certain management rules) or operational choices (regulation of machines). The routine procedure, and in particular those connected with risk management, can be described through the task model. Thanks to hypertext links, these models lead towards other forms of knowledge, such as text documents. The insertion of these models in an IT tool makes it possible to update them empirically (i.e. stemming from farmers' personal experiences) or from academic knowledge. The latter is introduced either by reconstructing and enriching certain documents, or by the direct insertion of engineering models. The limitation of using the MASK method to represent knowledge is the low level of accumulated expertise on the part of the farmers. If capitalizing experiences is possible on the scale of an annual campaign, it is much more difficult to obtain over longer periods, such as those of crop rotation, which can take around ten years (at the time of the interviews, most of the farmers had experienced only one or two crop rotations) (Duru, Papy, & Soler, 1988). However, this temporal limitation highlights the importance of cross-capitalization between farmers in similar production contexts.

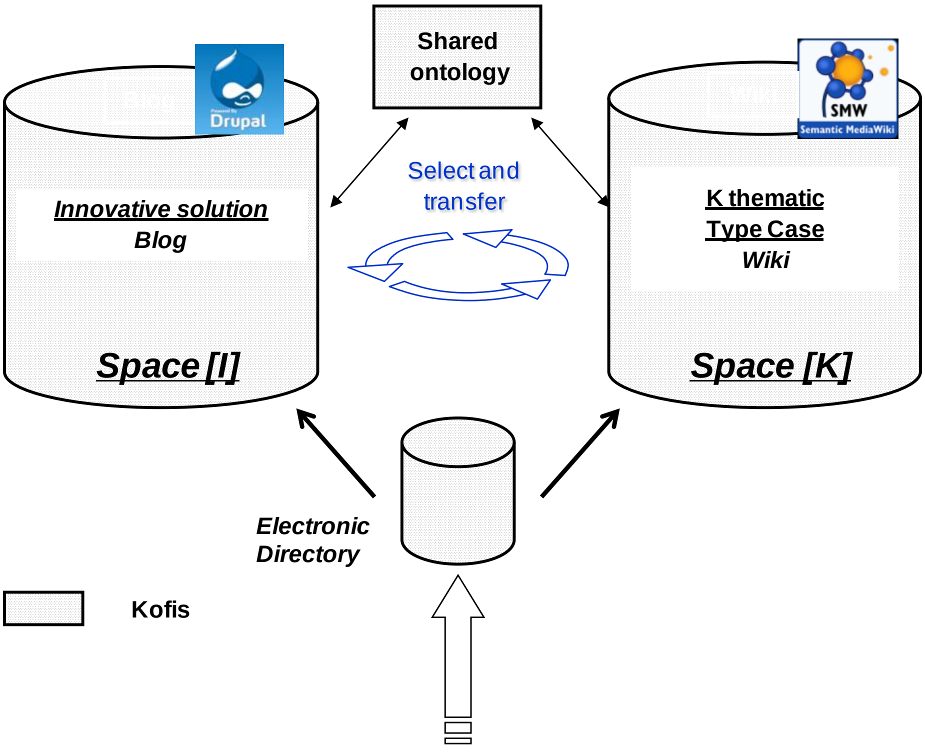

Figure 15: KOFIS architecture

A KOFIS prototype has been developed. Its architecture exploits the capacities of web 2, also called the social web, as well as the latest developments from the semantic web. Thus the tool enables the collaborative construction and storage of knowledge in the [K] space and exchanges in the [I] space. We have developed an ontology using SWM. Already, two agricultural projects, one of which has a national scope, are taking advantage of KOFIS architecture.

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