Transition towards low-input cropping systems: characterization of actionable knowledge for technical change

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Abstract: In the context of a current need for cropping systems adapted to new economic, social and environmental requirements, some agronomists have focused their research and advice activities on the re-design of cropping systems. Such adaptation requires firstly new knowledge on biological and ecological mechanisms supporting cropping systems less dependent on synthetic inputs, and secondly, tools (models, methods, participatory processes in which farmers have an active participation) for their design and evaluation. However, the new knowledge and tools proposed until now mainly address a *de novo* design of completely described cropping systems. Thus, questions remain concerning how farmers may benefit from these resources in order to undertake progressive technical changes in their own cropping systems, without necessarily having a clear description of one specifically targeted cropping system. This led us to study the way farmers engaged in such technical changes are managing the available knowledge in the design of their action. To this end, different characteristics of knowledge were analyzed, and used to describe the forms of knowledge mobilized or not by farmers. We proceeded with different types of interaction between farmers and agronomists to bring out the relevant characteristics: we surveyed farmers re-designing their cropping system and advisors helping them in this action, we organized meetings with farmers, supported with a set of information materials previously characterized. Axes of description of knowledge characteristics include forms of quantification, ways in which different time scales are addressed, ways in which it refers to uncertainty and risks, ways it refers to agronomic situations, and to onfield action. Knowledge characteristics were studied with the aim to understand how they influence legitimation and validation for action, and how they allow them to act in their particular situation, which will need further research. With a better understanding of what can be actionable knowledge, we finally aim at making proposals for adapting the knowledge produced to support technical changes.

Keywords: cropping systems design; actionable knowledge; knowledge characteristics; technical change.

Introduction

Innovative design of cropping systems based on ecosystem services raises questions about agronomic knowledge

Crop production must constantly adapt to new requirements and changing contexts. Particularly on environmental issues, recognizing the responsibility of agriculture in ecosystems disequilibrium and deteriorations (MEA, IAASTD) leads to give increasing importance to the environmental performance of agro-ecosystems, which sometimes competes with economic and social objectives. Cropping systems should then be re-designed to integrate these different objectives. Thinking about this activity of re-design has become an important part of some agronomists' activity (Hill & MacRae, 1995, Meynard, Dedieu, & Bos, 2012). Researchers have been producing knowledge and tools for designing innovative cropping systems that mobilize biological regulations. Design methods based on scientific knowledge, crop simulation models and decision support systems were produced. However, in many cases, objects or systems which need to be designed rely on unstable or scarce agronomic knowledge. Furthermore, recent work suggests that onfield uses should be taken into account during the whole design process (Cerf et al., 2012). This encourages implicating farmers in cropping systems design. This involvement raises methodological questions: how to organize workshop with farmers for instance (Reau et al., 2012, Lefèvre et al., 2013). But this also raises new questions about the content of the interaction, namely about the knowledge which is exchanged: Doré et al. (2011) suggest that knowledge sources should be more diversified to reach an ecological intensification of cropping systems, namely by taking more in account farmer's local knowledge. It requires a new reflexivity on which knowledge should be explored, and how this process should be steered.

Design processes can be distinguished according to the final outcome, and especially its relation to the current situations. *De novo* design of cropping systems aims at producing completely defined systems that break away from actual systems and realistic principles, in order to maximize creativity and mobilize innovative ideas. In agronomy, most resources for design are dedicated to this type of process. On the other hand, *step by step* design aims to progressively build changes in the actual systems from current cropping systems to innovative modes of production, while taking into account the specific constrains of situations. From an initial diagnosis, it allows farmers to perform and improve their system year by year, with successive evaluations and action planning (Mischler et al., 2009). Our work focuses on this second type of design process, with the hypothesis that farmers perform successive technical changes which have systemic consequences, and progressively lead to new innovative systems. Implementing such technical changes toward more sustainable practices, namely by implementing biological regulations, probably requires specific agronomic knowledge. Agronomic results concerning long term dynamics cannot be evaluated in the same way as, for instance, the use of a new product. Diversification of a crop succession by introduction of a new crop cannot be evaluated after the first year, on yield only. What knowledge allows the farmers to continue such changes? Are specific indicators needed? Which roles do the different types of knowledge play at different steps of the technical change? In the following section, we precise what specific approach of these knowledge problematic we propose.

Different approaches of knowledge in this context lead us to further explore knowledge characteristics in the content of information exchanges

The theoretical framework Agricultural Knowledge and Information System, proposed by Röling (Röling, 1988; Röling & Engel, 1990), is often mobilized to study knowledge and information dynamics between the diversity of stakeholders involved in sustainable agriculture development. It recognizes the innovation potential of all stakeholders, including farmers, and support thinking of new institutional organizations able to improve capacities to innovate. Cash et al. (2003) studied different cases of agricultural research and development; and suggest that knowledge is more likely to be influential for sustainable development if it is perceived as salient (relevance of assessment for needs of decision makers), legitimate (production of knowledge and technology respectful of stakeholders' divergent values and beliefs, unbiased, and fair in its treatment of opposing views and interests) and credible (scientific adequacy of technical evidence and argument). They argue that efficient systems to reach these criteria make use of boundary organizations and boundary objects, which act at a boundary between science and policy arenas. However, this helps to think about how to organize relations between stakeholders, but not directly to precise what knowledge should be exchanged and how.

Magne et al. (Cerf & Magne, 2007; Magne, Cerf, & Ingrand, 2011) aimed at identifying informational resources mobilization logics. Resources where characterized according to their support, origin, content and function. This allowed to describe how farmers use different sources of information and roles assigned to each source, but further description of knowledge that is mobilized is necessary to match the objective to understand how specific knowledge participate into the construction of capacity for action.

Others focus more specifically on interactions between advisors and farmers (Ingram, 2008, Klerkx & Jansen, 2010), and the opportunities for these interactions to address sustainable farming practices. Ingram (2008) distinguishes knowledge exchange encounters (KEE) according to the behavior (proactive, reactive) of both farmer and advisor. Among "expert" KEE, "divergent" KEE and "facilitative" KEE, the latter seems to be the most promising for promoting sustainable farming practices. Agronomists and farmers work in partnerships, combine their experience and knowledge and jointly set objectives based on the farmers' needs. These are more equitable encounters than the others in terms of power in the relation, and knowledge value. However, it is difficult to artificially build such a KEE. Questions remain for an advisor, even if he feels like implementing such a relation, concerning the path of action. Several studies insist on the need for "soft-skills" in order to implement a facilitative encounter (Klerkx & Jansen, 2010, Ingram, 2008, Kristjanson et al., 2009). Our hypothesis is that it can be artificial to separate technical skills from social skills, and that facilitative relationship between agronomists and farmers also depend on the different elements of knowledge that are actually discussed and shared in such encounters. Ingram and Morris (2007) used the distinction between know-what (knowledge about facts), know-why (knowledge of principles, rules and ideas of science and technology), know-how (skills, the capability to do something at practical level), suggesting that these forms of knowledge are actually in complex relationship. Thus, we argue that an analysis of knowledge exchanges in their content (both know-what and know-why) can provide useful information to advisors about how to create facilitative KEE (know-how for advisors). We suggest that giving farmers the ability to change also requires adequate combinations of elements of knowledge. This article proposes a type of characterization of knowledge aimed at better identifying these actionable knowledge combinations, which will later allow to study how knowledge is legitimized and articulated by farmers in order to construct their capacity of change.

Analytical framework: an organized list of characteristics

Analyzing knowledge exchange and use according to the contents can be done at different levels, focusing on different aspects depending on our various objectives. In this section, we specify the type of analysis we realized, and the main theoretical bases we used to construct a group of characteristics of agronomic knowledge. What we call agronomic knowledge in this analysis corresponds to all the types of cognitive resources that concern biological, chemical and physical processes and their interactions that occur in agro-ecosystems, the farming practices that can influence these processes and all the rules, methods and tools which help organize and decide of farming practices.

The aim of such an analysis of knowledge characteristics is to understand which specific knowledge contributes to take the decision of a change, to construct the capacity of action and to perform action for a technical change. That is the reason why we focused on aspects that we found decisive: these aspects are linked with the 'usability' of the knowledge. This is different from what other researchers have focused on: for instance, a linguistic approach that opposes monologic ("aboutness", the speaker says what is, without engaging himself) and dialogic ("withness", the speaker engage his own experience, and expect to suggest questions and reactions) types of account from a researcher or a peer (Shotter, 2008); or a strictly cognitive study of how specific formats of data or theoretical representations (lists, graphs, arrays, …) influence agents' performances and theorizing capacities by providing different inferential affordances

(Vorms, 2010). Indeed, our analysis aims at producing conclusions that would be useful for agronomists.

In the following section, we describe the main characteristics we choose to analyze in agricultural knowledge. The characterization is based on seven axis, that discern groups of items (Table 1), described here. These groups were chosen based on literature from both cropping systems agronomy, and activity theories (precise references are given along the description below). Precise modalities within each group were also completed with exploratory reading of information resources on sustainable practices.

1. Quantification is a first aspect that characterizes knowledge for our objective. Forms of quantifications are diverse. We chose to distinguish (1.b) mean values, extreme values, distributions, imprecise order of magnitude, and estimate as a fraction without reference to an initial value (e.g. "erosion reduced by one third"). Inspired by the scheme proposed in *evidence based policies* approach, we distinguished different roles that quantifications can play (1.a). They propose three types of evidence that can be mobilized to characterize the role of quantification: evidence of existence (e.g. census to enumerate a population), evidence of mechanism (a causal relation established between two specific events), and evidence of efficacy (an action producing an expected result) or harmlessness (an action does not produce adverse effects). In addition, quantification can be mobilized in a specific knowledge in order to obtain, or confirm, a qualitative knowledge. The value in itself then does not have a direct significance, and is not used as a generic value, but allows to deduce a qualitative result (e.g. comparison of species for N uptake efficacy). Another role of quantification we considered here is the precision of an action modality (e.g. precise amount of mineral fertilizer to use). Finally, quantification can also serve an estimation of an optimum value to reach, in order to obtain a given objective. These roles of quantified values are important characteristics, because they make it possible to consider the uses that farmers may do from these quantifications in the building of their decision-action.

2. A second type of characterization concerns temporality and dynamics addressed by a specific knowledge. Time scales addressed can differ (2.b). Three categories are chosen: knowledge which focuses only on the time scale of the object or practice considered, knowledge which mentions longer time scales but associated to results and objectives still at the considered object time scale, and finally knowledge that address a longer time scale, for instance corresponding to a system including the object or practice of interest. To illustrate these categories, the introduction of a new crop in a succession can be linked to knowledge dealing only with technical operations on this crop, to knowledge on nutrient dynamic in soil that can influence the following crops, or to knowledge that concerns the effect in weeds reduction on other crops. Another characteristic of interest is the use of the time dimension (2.a): mainly, we distinguished knowledge on comparisons of static states at different times (time is used as a factor that multiplies the number of observations), and knowledge that allows to describe specific dynamics, whether linked to a farmer's action or not (tendency, progressive evolution).

3. A third axis of characterization of knowledge corresponds to the way risks are taken into account. Managing risks and uncertainties is a particularly important part of activity of farmers heading toward more sustainable practices, mainly because curative solutions are less available, and also because practices are much more dependent on specific local situations. We consider that taking these risks into account can be done by anticipating the limits of a definite practice (3.a) in case of specific disturbances (e.g. draught), or by giving indications on possible irreversible effects that a practice can produce in certain conditions. Uncertainties are also addressed in different ways (3.b). We categorized knowledge by taking into account whether: (i) it mentions remaining ignorance associated; (ii) it assesses sensibility to certain parameters; or (iii) it evaluates probabilities not to obtain the expected result.

4. To present the four remaining categories of characteristics, it is useful to mention what is called a “scheme” in occupational didactics (Pastré, Mayen, & Vergnaud, 2006), defined as “an invariant organization of activity for a defined class of situations”. A scheme is composed with (i) an objective, sub-objectives and anticipations, (ii) rules of action, information taking and control; (iii) operational invariants (concepts-in-action which are concepts that organize activity, that give benchmarks for realization of an action, and theorems-in-action, which correspond to propositions considered as true about reality); and (iv) inference opportunities (which correspond to information and indicators that agents take from the situation). Four axes of characterization of knowledge try to focus on elements that can contribute to the construction of such schemes. We first proposed to characterize how different objectives are explicitly (or not) related to the knowledge, and the elements that could make it converge with farmers’ problem situations (4). Objectives can be numeric (e.g. evaluate a nitrogen quantity that will be brought by a cover crop to following crop), logical (e.g. how to maximize interests of a cover crop in a rotation), or conditional (e.g. choose the most appropriate cover crop species according to given situations and farmers’ motivations). We also observed whether an objective indirectly linked to production of crops is associated to knowledge, such as maintaining biodiversity or specific ecosystem services. This is particularly relevant for characterizing knowledge exchanges designed to address sustainable farming practices (Klerkx & Jansen, 2010).

Table 1: Framework of knowledge characteristics

1.	quantifications and types of evidences	a.	what for?	1	to explain or measure a mechanism
				2	to obtain, validate or confirm a qualitative result
				3	to measure an effect (positive, negative, danger, safety)
				4	to precise an action modality
				5	to estimate an optimum value to reach
		b.	which forms?	1	estimation (mainly an effect) as a function without reference
				2	imprecise order of magnitude
				3	extreme values
				4	values-distributions
				5	precise mean
		c.	reference to?	1	to a value farmers can measure/estimate
				2	local value
2.	temporality and dynamic	a.	dynamic addressed	1	comparisons of different static states (time as a factor or diversification)
				2	dynamic related to possible farmer's actions (trend, progressive evolution,...)
		b.	time scale addressed	1	time step of the main concerned object (ex: cover crop)
				2	longer time scale but measures and results stay on object's time step
				3	time step of a system including object of concerned practice
		c.	spreading of the problematic in time	1	objective linked to successive steps, to long term dynamic
				2	setting time of an expected result
3.	Risks	a.	limits of a farming practice	1	in case of specific disturbance
				2	unexpected and irreversible effects
		b.	uncertainties	1	ignorance
				2	sensitivity to certain parameters
				3	quantification of a variability
				4	possible losses
				5	probability not to obtain expected result
4.	objectives explicitly related to knowledge and convergence with problematic situations	a.	objective associated to the knowledge	1	numeric
				2	logic
				3	conditional
		b.	objective not directly related to crop production		
		c.	interests of a farming practice and conditions to obtain them		
		d.	testimonies and opinions		
		e.	functions expected with a practice and underlying mechanisms distinguished		
		f.	structure based on successive key steps of action		
		g.	elements to precise definitions of objects concerned and frames they are included in		
		h.	judgment with implicit positive direction		
5.	agronomic reasoning	a.	functional links	1	interactions between functions (of a technic or object)
				2	interactions with other compartments
		b.	link between a function and (eco-)physiology		
		c.	functions and sub-functions are prioritized		
		d.	effects of a new practice on a system		
		e.	general rules and recommendations		
		f.	general rules with modulation factors		
		g.	mechanisms	1	to explain an agronomic logic
				2	to explain a result
		h.	logical result presented without measured data or results		
		i.	options comparisons	1	in accordance with a goal
				2	without reference to a specific goal
				3	on logical and cost criteria, without agronomic results
		j.	other possible practice(s) with the same objective, same function		
6.	references to agronomic situation	a.	situation in which knowledge was created (testimony, trials)	1	large context (law, pollution, main practices, ...)
				2	place
				3	regional agronomic context
				4	field situation and type of soil
				5	historical background
				6	reasoning
				7	pictures
				8	local agronomic results and references
				9	personal experience related
		b.	farmers' situation	1	interactions with other practices on the farm
				2	summary description of the cropping system
				3	benchmark to observe in situation (stand states,...)
				4	limiting factor in the situation
				5	situation characteristics (mainly soil types)
				6	principles of reasoning to guide situation characterization
				7	elements to refer to an initial situation
7.	On field action explicitly attached to knowledge	a.	example	1	typical action with precise (quantified) steps
				2	illustration of a principle (without results)
		b.	indicators to confirm that action performed is the expected one		
		c.	indicators to monitor the action	1	when: precise date
				2	when: mean date with modulating factors
				3	when: benchmarks in fields states
				4	benchmarks related to other related actions
		d.	indicators to evaluate the effects of a specific action	1	judgment without clear or precise reference
				2	precise and generic point of reference

Indeed, we noticed that any given practice can be addressed with different associated objectives, and thus be considered whether or not as a sustainable farming practice. Another item is related to the presence of elements of definition: such elements contribute to precise the approach of agronomic objects that the knowledge mentions, and specify the frames they are included in. This is suggested by the hypothesis that farmers may sometimes need to think an already known object or practice in a new type of system, in order to better know how to manage it, to evaluate interests for their own cropping system. Remaining characteristics of this axis are more related to the way knowledge is structured within a document used as a support for information: is knowledge presented according to the various steps of action? Or is it merely a compilation of testimonies and opinions? Are objectives that farmers can expect from a specific practice and underlying mechanisms clearly distinguished?

5. The following axis of characterization describes the elements that can contribute to an agronomic reasoning (5). This can be partially related to "know-why" form of knowledge in Lundvall and Johnson's typology (1994). Knowledge can concern functions associated to a practice or an object (5.a). What are the interactions between different functions? (e.g. for cover crops, producing biomass on one hand, keeping a C/N ratio low for rapid mineralization on the other hand). Are there some plant-physiology aspects related to the functions expected from this plant? Are different effects of a practice on an existing system (including unexpected ones) mentioned? Knowledge can also correspond to general rules or recommendations (such as a date and density of sowing for a new crop). These recommendations can include factors of modulations or not, and effects of these modulations. Knowledge can also address mechanisms underlying expected functions. This can be in order to explain an agronomic logical inference (e.g. legumes crops first use soil N before mobilizing air N, then it is possible to fertilize them for initial growth) or in order to explain a result (e.g. facilitation and competition in intercropping). Finally, we note that knowledge can correspond to the comparison of different technical options, such as plants species for instance. All these elements are supposed to contribute to the construction of a cognitive model for action in a range of situations (Pastré, 2006).

6. Occupational didactics insist on the fact that both cognitive and operative representations are involved in activity. An operative model corresponds to concepts that allow actors to make a diagnosis of a specific situation and to adapt their action. While cognitive model allows understanding "how it works", operative model allows to understand "how it is driven". We relate to this notion the last two categories of characteristics, which are the different elements that refer or guide in making reference to an agronomic situation (6), and finally the way the onfield action is addressed in knowledge (7). We think that it is necessary to distinguish references that are made to the situation in which knowledge was produced (usually farmers' testimonies and trials descriptions)(6.a)) from those made to the farmer's situation (6.b). These last ones correspond to conditions that are required in order to obtain a specific result, or to indicators which will make adaptations to the situation possible. Knowledge can address interactions between practices, namely practices that a farmer could implement and a practice already mobilized (e.g. introducing a cover crop may limit opportunities to mechanically treat perennial weeds between two crops, leading to the need to modify weeding strategies). Reference to onfield farming situations can also simply be made by describing, whether the general type of system (e.g. organic cropping system), whether specific characteristics such as types of soil, or a specific limiting factor that would be to considered. Farmer can also make use of benchmarks, such as stand state or soil humidity. Furthermore, we propose to asses if knowledge allows evaluating an 'initial' situation the farmer would be facing. With 'initial' situation, we mean a characterization of a state of the system which is supposed to evolve. The effect of a practice may not be the same according to this 'initial state'. For instance, does assessment of a weeding potential of a temporary forage stand take in account an initial weed pressure or population, and is it taken in account to generalize the proposed results?

7. Finally, we characterized knowledge according to the way it explicitly mentions onfield farming actions, which means that some very practical aspects of implementation of a practice are mentioned. This can correspond to a number of relevant examples of how precise actions are done (7.a), whether realized or hypothetical, based on agronomic principles. It can also correspond to indicators that allow a diagnosis of the action (7.a, b and c respectively): (i) confirming that action performed is the right one, (ii) indicators for monitoring the action, and (iii) indicators for evaluating the impact (which may include, for instance, measurements of environmental indicators).

The items proposed to characterize knowledge are not exclusive. The framework they constitute must be considered as a tool for the identification of different types of cognitive resources. The aim is not to fulfil the most numerous characteristics. On the contrary, we hypothesize that different characteristics of knowledge are necessary for different classes of situations, and play different roles in farming practice changes.

Methods

Documents analysis on a specific practice: cover crops as a relevant example

We used this grid to characterize information mediums that concern cover crops. Implementation of cover crops to replace bare fallows is a practice that is explored by a growing number of scientific publications (WOS: Title=”cover crop*”, 170 items published in 2012 against ~80 in 2000). In France, legal requirements for vulnerable areas, regarding water pollution by leaching nitrogen, made compulsory different modalities of soil coverage during fall and winter. Cover crops can fulfill the function of a nitrogen uptake (catch crop) through this period, but they also have a range of different agronomic and ecological functions in agro-ecosystems (soil structuration (Calonego & Rosolem, 2010), weed management (Campiglia et al., 2010), N remobilization for following crop (Justes, Bedoussac, & Prieur, 2009), C and N soil storage (Sainju, Singh, & Whitehead, 2002), disease reduction and beneficial insect preservation (Snapp et al., 2005)). It can thus be considered as a farming practice leading to more sustainable farming systems. It is necessary to note, nonetheless, that it can correspond to different types of actions from farmers’ point of view: an action for productive performance and dedicated mainly to yield optimization, but also maintain biodiversity and provide ecosystem services not directly linked to agronomic production. This makes it even more relevant to analyze the diversity of knowledge produced and exchanged on such a practice.

Forty-six information documents were analyzed for a thorough knowledge characterization. These were scientific articles (8), technical institutes communications (10), communications from ‘Chambres d’Agriculture’ (French public extension services)(8), and articles from agricultural press (20). They were read twice, and we allowed ourselves to make the framework evolve in precise characteristics if new ones were brought out from documents. No specific language or textual analysis was done so far, but it remains a possible relevant method for larger analysis.

Case study: a group of farmers who changed their nitrogen fertilization strategies

We chose to study knowledge exchanges in groups of farmers. Nave et al. (Nave, Jacquet, & Jeuffroy, 2013) have shown that extension groups are correlated with low input system in a region of France. These groups influence the farmers’ approach of sustainability and offer opportunity to gather information so as to reduce uncertainty (Rivaud & Mathé, 2011). Furthermore, Darré (1994) studied how local professional groups contribute to the creation of their own norms of practices. These are arguments justifying that such groups are adequate spaces for analyzing knowledge mobilization. The group concerned here is a group of 12 farmers (9 attended the meeting we relate here), who progressively adopted integrated production cropping systems. The material used in this section is taken from a meeting day of the group, during which we offered farmers to participate in a joint discussion about the specific theme of "the strategies of nitrogen fertilization of winter wheat". Two specific questions were asked: first we wanted them to explain *how* they actually proceed to plan and realize nitrogen fertilization. Second, we asked them to precise what changes they had carried out, compared to what they used to do, and what happened that made them change their strategies. We selected relevant parts of the discussion in order to identify the knowledge that has been involved in different technical changes related to nitrogen fertilization, and present them in a chronological order corresponding to their evolution. The wheat sowing practices were previously affected by the integrated production strategies, namely a lower density and the late sowing date.

Findings from the application of the analytical framework

Documentation supports dealing with a same practice show a great diversity of characteristics

A first result is that, although all documents deal with the same subject, there is a great variety in the characteristics we analyzed, between types of documents (which can sometimes be related to traditional forms of communications), but also within each type. Most common characteristics were logical objective (4.a.2) (48%), and time scales longer than the concerned object mentioned but measures and results still concerning object's time scale (2.b.2) (50%), logical result without measured data (5.h) (46%). However, this last characteristic is more specific of agricultural press articles (11/20) than scientific articles (2/8).

In scientific articles, logical objectives were often associated with a numerical objective (6/8 for both characteristics), which was not the case for documents from the agricultural press (0/20) and Chambres d'Agriculture (0/8). Indeed, even when these documents present for instance the effect on the following crop yield, they finally conclude on a qualitative result. On the contrary, the scientific articles are not structured according to successive steps of action (4.f) (0/8), whereas documents from technical institutes and Chambres d'Agriculture mostly are so (7/10 and 5/8 respectively). For instance, these steps can refer to the choice of a given cover species, its sowing, and the destruction. This could be explained by the role played by technical institutes which are to provide information for managing crops basically.

Interactions between functions (5.a) associated to cover crops were not discussed in a majority of documents (15% of all documents). The main interaction documented was the balance between early biomass production that allows catching soil nitrogen efficiently, and the decrease in the N content of the plant when cover crops develop through a complete cycle, also including seed production that can increase weed populations. Even when mentioned, these interactions where not quantified. Another interesting result is the low number of scientific articles which address action in fields (only one article provided an indicator to evaluate the effect of action (7.c)).

Knowledge mobilizations in the group of farmers

We have seen that the characterization of knowledge we propose can be useful to bring out the variety existing in knowledge that concerns a given practice. However, this did not give any information about how it corresponds to knowledge which is actually mobilized. The following section shows that the framework for interpretation of knowledge characteristics also allowed to analyze which knowledge exchanged in agronomists-farmer interactions was useful for technical changes.

The farmers of this group mentioned the inconsistency in their former practice consisting in fertilizing wheat just before adding a growth regulator. One specific type of knowledge was cited as decisive in changing corresponding practices. This was brought by an encounter with a researcher:

“A scientist told us that finally, even if it was theoretical, a wheat which was grown with an NNI 0.8 might as well make it through… as far as the deficiency or semi -deficiency was not too extended in time nor too intense, and that the N content was lower at a time, as far as nitrogen is provided at a certain time, hence the idea to provide N from bolting, the NNI was up and there was no harm on the final yield." (all reported speeches are translated by us)

From this type of quotations, we can deduce what farmers remember from knowledge exchange. Thus, we use our characterization framework to identify what made knowledge useful for them, according to their practices, needs and objectives. Here, we notice that the deficiency was already known as a concept, and its definition did not change fundamentally. What changed was its interpretation, and the way it can be related to the final yield. For these farmers, the NNI (Nitrogen Nutrition Index) is a quantified indicator of a mechanism that allows to explain a result theoretically (5.g.2). The value of the quantification was not in its accuracy, but in its help to explain a mechanism (1.a.1); indeed, no one in the group tries to measure the NNI in his situation. What farmers used was more related to the dynamic (2.a.2), and the information on risks of N deficiencies (3.b.4). The objective explicitly associated to the knowledge was to maintain an acceptable yield while minimizing nitrogen input (4.a.3), distinguishing the final yield from the underlying mechanism (4.e). They do not use NNI as a benchmark for action monitoring (7.c), but as an element that better describes wheat growth dynamic (physiology)(5.b), which finally support an agronomic reasoning for fertilization which comply with their objective.

"Sowing less densely, so not looking for biomass, also encouraged us to shift the first fertilizer input since we have no interest in nurturing and producing biomass."

This shows that the new interpretation of nitrogen deficiency also led to a coherence between techniques (late sowing, low density, late first fertilization) (6.b.1), by better understanding interactions between the functions of N fertilization (biomass, standing ability of the plant, number of shoots)(5.a.1). As they further explained, their objective is not to maximize the biomass anymore, but to maximize the flowering shoot proportion, which is an indicator they can measure to evaluate their action (7.d.2).

“The nitrogen balance method, one can modulate it, but FARMSTAR, if it says that much, it’s that much”. Two tools were commented regarding the knowledge or indicators they provide. They were Jubil® (an indicator of nitrogen nutrition of the plant obtained from juice extracted from stem bases, providing quantitative recommendations for fertilization), and FARMSTAR (tool using satellite imaging in order to provide a personalized advice on fertilization adjusted on plant growth dynamic). In addition to the fact that these tools had the implicit objective to keep an NNI superior or equal to 1 (4.a.1), which goes against their own objective, they revealed that another limiting characteristic of these tools was to provide a quantitative information (1.b.5, 1.a.4) with no possible modulations nor information on how to modulate this recommendation (5.f). The double density strip is another method consisting in doubling the normal sowing density on a strip, in order to observe early deficiencies (6.b.3), taken as a signal for deciding of fertilization (7.c.3). It was mentioned that this indicator does not provide sufficient information for their action: "This is a trigger indicator, it tells us ‘from now wheat needs nitrogen’, it's not a confirmation that we will fertilize and that it will be efficient!” “We suppose that it is efficient but we don’t have tools that measure whether it is at 80% or 60%”.This quotation suggests first that the double density strip method does not directly respond to the objective of efficiency, and second that rather than an indicator for monitoring action, they would need an indicator confirming that they have performed the appropriate action (7.b). In addition, it was brought out that new indicators are needed for monitoring action. For instance, a farmer told the group that on a field, he did not bring the last 20 kilos of nitrogen per hectare that the balance approach would have recommended, but did obtain the yield expected. Another farmer reacted: "Fortunately you did not put the last 20 kilos" The first replied: "yes, but maybe I could have put 20 more!" This revealed the need for an indicator that allows to adjust the amount of nitrogen required for the wheat growth to the dynamics of each specific year and field situation. Again, we were faced with the need for decision tools or indicators enabling modulation around a static recommendation (5.f, 7.c.2). This also leads them to request knowledge on the main mechanisms taking place in soil (e.g. mineralization in April-June)(5.g).

Conclusion

The aim of this article was to propose a framework of general items one can refer to in order to characterize knowledge. Its application to the analysis of a variety of documents concerning a sustainable farming practice (cover crops) allowed to show that the corresponding knowledge was very diverse in its characteristics. Only few resources take into account initial situations which would affect the use and results of using cover crops. Likewise, variations around a precise recommendation are scarcely dealt with and analyzed, as well as risks associated to this practice.

For an advisor, addressing a sustainable farming practice could thus be done in many different ways in a knowledge exchange with farmers in terms of elements of knowledge. Identifying them in order to complete what lacks for action, and to manage combinations of characteristics, could be facilitate by the framework proposed here. It still needs to evolve toward simplification in order to play this role. The close study of the farmers' group technical changes concerning fertilization shows that the type of characterization we propose can help identify knowledge which is useful in order to support such changes. The same group mobilized knowledge of different characteristics at different steps of the interaction, according to different steps of changes. This was suggesting several hypotheses about important aspects of knowledge contents that influence its actionability. These remains hypothesis at this stage of our work, and will be further explored through other surveys. They vary according to the role this new knowledge might play at a specific step of a technical change. To precise this, more analysis of interaction between farmers and agronomists are planned, in order to bring out how knowledge of different characteristics is mobilized along a timeline, in different steps of technical change. Indeed, the work presented here mainly focused on possible contents of knowledge exchanges, but it is a necessary base for further studies of processes of knowledge articulation and legitimation.

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