Norwegian University of Life Sciences
Faculty of Veterinary Medicine and Biosciences
Department of Plant Sciences

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A Sociological Approach to Crop Diversification

Léa Vereecke

Abstract

Worldwide the diversity of cultivated plant species decreased for the past decades under the influence of the fast development of farming technologies. This lack of diversity has environmental impacts including water pollution. At a national scale, in developed countries it appears that agricultural sector is structurally locked-in this situation. However local initiatives involving agricultural stakeholders and local institutions appear as promising way to increase crop diversity. Increasing understanding of farmers and market on a defined territory was seen as a way to better target initiatives oriented toward crop diversification. To answer the need for water quality improvement, focus was made on low-input crops. An overview of current situation was drawn by short market assessment and a deep analysis of farmers' behaviors and attitudes. Through semi-directive interview, I brought to light structural and psycho-sociological factors associated to crop diversification. Main finding is that farmers' behavior toward their peers and their priority management are the first factors to consider in programs which aim at increasing crop diversity. Scenarios involving local institutions and stakeholders with a shared goal of increasing crop diversity at a territory scale were shaped.

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1. Introduction

In 1996, the Food and Agriculture Organization of the United Nation reported that "*75 percent of the world food is generated from only 12 plants and 5 animal species*". This low level of crop diversity is a result of diverse enhancing factors identified at different scales. At the international scale, industrialization allowed development of farming technologies such as mechanization, plant breeding and chemical inputs which rapidly developed in the 1900's (Harwood, 1990). Combination of those evolutions allowed an expansion of farms size and specialization and intensification of farming systems. At European scale, the productivity oriented measures that first shaped Common Agricultural Policy enhanced this intensification (Rizov, 2005). At national scale under the influence of environmental conditions and agro-industry development, specialization of agriculture at regional scale accelerated (Fuzeau et al, 2012). Finally, at the farm scale, farming systems specialized either on crop or cattle production (Schneider et al, 2010). As a result, food diets are poorer, biodiversity decreased, input-use increased and farms became more vulnerable… and each of those effects has side effects including increased *water pollution* (Thrupp, 2000).

In 2000 the European Parliament together with the European Council adopted the Water Framework directive in the Official Journal. The adoption of such directive highlights a raising concern on water quality. For each river basin, European countries have to settle a management plan with the aim of reaching "*good status for all waters by a set deadline*" (European Commission, 2000). In order to meet this goal, water agencies were established on each river basin with the responsibility of defining and adopting those management plans (Barataud et al, 2014). In this context, in France, the Seine Normandie water agency acknowledged that *increasing crop diversity by introducing low-input crops* is a leverage to decrease the use of pesticides and nitrates in agriculture.

In 2013, the French ministry in charge of agriculture and environment ordered to the French institute for agronomical research to investigate brakes and levers to diversification of culture in France at the agricultural farm and chains scales (Meynard et al, 2013). They made and validated the hypothesis that, at a national scale, crop diversification requires unlocking current agricultural structure (Cowan et Gunby, 1996). Indeed, as pointed out by Barbier et al (2010), part of the problem is that actors of the agricultural sector feel that nothing can change before the others change. However, they stressed that enhanced partnerships between different actors of agricultural sector toward crop diversification at *local scale* could accelerated changes at larger scale.

By reviewing successful programs, Benoit and Kockmann (2008) proposed a general method to improve water quality at the water-catchment's scale. They emphasized that involvement of local actors and institutions in both territorial diagnostic and solution building process is needed. Initiation

of their method consists in involving farmers through comprehensive interviews. However, the two researches on changes previously introduced (Barbier et al, 2010; Meynard et al 2013) did not include *direct interactions with farmers*.

By analyzing farmers' attitude, Compagnone and Hellec (2014) investigated on the potential link between farmers' networks and their dynamic of change. They "*found a link between network type and the dynamics of changes in members' behavior*". According to Mercklé (2011), dealing with network, approach can be on entire network or on personal network. The principal limit using the "complete network" approach is the potential differences between the observed network and the. The "*personal network" approach* has the advantage of bringing out the importance accorded to network by interviewee in the sense that the network is drawn according to statements of the respondent.

The French Aube department's agricultural landscape is currently shaped by a triennial crop rotation. My hypothesis here is that a better understanding of farmers' attitude toward crop diversification would be an efficient first step toward introduction of low input crops.

In order to avoid potential contradictions associated to crop diversification (Lamine et al., 2010) I felt the need to reflect on low input crop selection. Moreover, I considered marketability as a first need for a farmer to cultivate a crop. By contacting buyers that are directly concerned, I wanted to get their point of view on those markets. Going to farmers' survey, I assumed that further than technical and logistical considerations highlighted by Meynard et al (2013) it exists psycho-sociological aspects that influence farmers' attitude. According to Ajzen (1989) "*An attitude is an individual's disposition to respond favorably or unfavorably to an object, person, institution or event or to any other discriminable aspect of the individual's world*". By psycho-sociological I consider cognitive, behavioral and affective aspects (Rosenberg and Hovland, 1960) as well as farmers' interactions with their agricultural information network. The objective is on describing and understanding those different farmers' behavior toward crop diversification in order to help local institutions better targeting their crop diversification programs.

2. Material and Methods

2.1. Understanding the local context

2.1.1. Aube department, Barrois and Pays d'Othe natural regions

The Aube French department is located in the North East of France and the South West of Champagne-Ardennes region. Aube is divided into different "natural regions" which present distinct soil and climate conditions and different wild and domesticated flora that fit those conditions. The Northern part of the department is homogeneous and characterized by plains presenting a chalky soil. It is part of the "chalky champagne" known for its fertile soil allowing large scale highly yielding agriculture and viticulture. By contrast, the Southern part shows three distinct zones. The south western part, named "Pays d'Othe" is part of a wider calcareous massif covered of clay and flint (Chantriot, 1895). On the hillsides, we observe a superficial clay-limestone soil with flint. By contrast, on the plateau soil is composed of silt and sand. At the plot scale there is a high heterogeneity. The South Eastern part named "Vignoble du Barrois" is characterized by superficial clay and limestone soil on the plateau, mostly clay on the hillsides and a mix of clay and silt in the valleys (Groupe Barrois, 1988). Barrois and Pays d'Othe are the two natural regions concerned by this research. Between those two regions, we find the "Humid Champagne Region" which soil is mainly composed of clay and marl.

2.1.2. Local agricultural routine

According to data from the local agricultural census, sixty-two percent of the department is devoted to agricultural purposes (see data appendix 1). While arable crops dominate in terms of surface, viticulture represents forty-eight percent of agricultural economic value (Alloy et al, 2011). Winter wheat (*Triticum aestivum*), rapeseed (*Brassica napus)* and winter barley (*Hordeum vulgar*) cover large part of the department and have an importance at the national scale (see figure 1). Beetroot for industry use, potatoes and hemp also cover an important part of Northern department (Alloy et al, 2011).

The total number of farms has been cut by thirty-two percent between 1988 and 2010 while the area declined only by zero point two percent. (see appendix 1). Thus, lands are concentrated in the hands of few farmers: in 2011, the mean size of farms was one hundred forty three hectares. The marketing of seventy percent of agricultural products is operated by two main "storage agencies". What I call here a storage agency is an actor who collects stocks and sells agricultural raw material. One is "France's top private buyer of cereal" (Soufflet Group) and the other is a "farming and food industry cooperative" (Vivescia) created in 2012 from fusion of two smaller cooperatives.

Going to natural regions' scale, the North is more diverse than the South thanks to more suitable soil and climate conditions (see 2.1.1.). As evidence, mapping the score of rotational diversity (see appendix 2), we observe that Barrois and Pays d'Othe are the less diversified areas of the department (see figure 1).

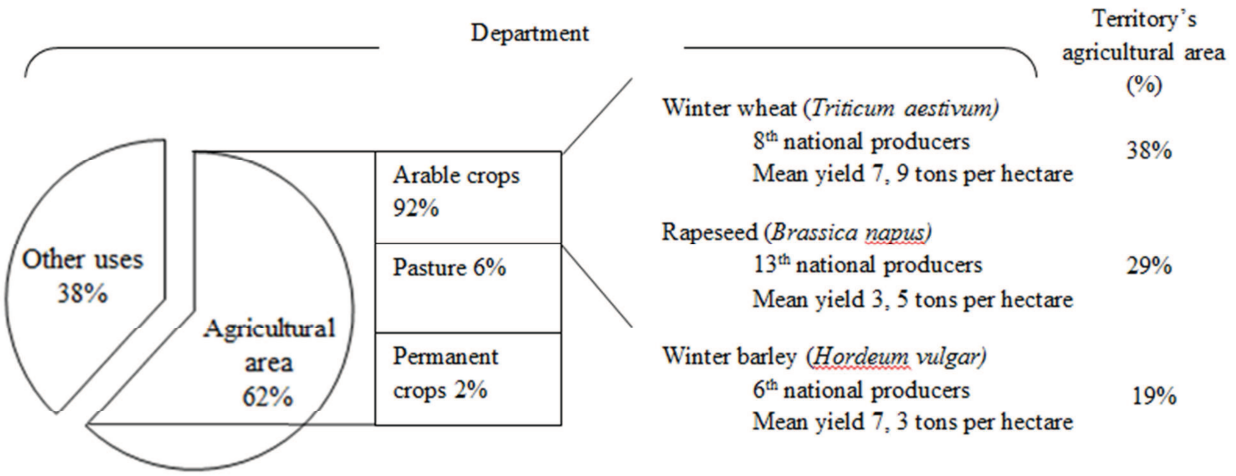


Figure 1 - Local agricultural routine (data from Vegellia[1], 2012 & 2013) ("territory" refers to Barrois and Pays d'Othe together)

Resulting from this agricultural routine, Aube together with three other departments of the Seine-Normandie river basin represent 50% of the pesticide bought on the whole basin and only 30% of the arable land surface due to both intensive crop production and viticulture (Comité de basin agence de l'eau Seine Normandie, 2013). Precisions about water quality can be red in appendix 3.

2.1.3. Agriculture and water pollution: local institutional actors

This research project was funded both by the water agency and the Chamber of Agriculture and conducted on the behalf of the Chamber of Agriculture in relation with the MAPC.

Seine-Normandy water agency is a public institution which belongs to the ministry of ecology. It has the role to support projects aiming at improving management of water resource, decreasing water pollution or restoring ecological balance of rivers (Agence de l'eau Seine Normandie).

Aube Chamber of Agriculture voices the concerns of farmers and any actor linked to agriculture from the departmental scale to the state scale in the frame of their consultative role (rural and marine fishing code, Art D511-1, 2011). The Chamber includes specific units named "Groupe de développement agricole" (referred as GDA). Their role is to create stimulating environment for project emergence in a defined area, transmit innovative practices and favor group working between farmers. Farmers that are willing to participate pay a fee to belong to the group that operates on his

[1] Network for agricultural references in the French department of Aube

area. This fee is used to pay a referent advisor on this area. This advisor is sending a technical note each week or more often if there is a specific issue. A field excursion on a farm is weekly organized for farmers to meet and ask questions while looking at crops' development. Other occasional event focusing on a define topic can also be organized by the advisor.

In 2007, the Seine-Normandy water agency and Aube Chamber of Agriculture created a new unit together with the Departmental Council. The unit was named "Mission Agricole de Protection des Captages (referred as MAPC). This partnership was initiated with the goal of developing technical assistance for preservation and improvement of drinking water and meets the objective fixed by the Water Framework Directive.

2.2. Methodology

The project was carried out during a fieldwork period of twenty six weeks. Before starting the fieldwork, a list of crops that were considered as low input and suitable for the territory[2] was created (part 2.2.1.). The market potential of each crop was assessed to serve operational needs. In parallel I carried out a farmer survey followed by propositions for improvement of the current situation (see figure 2).

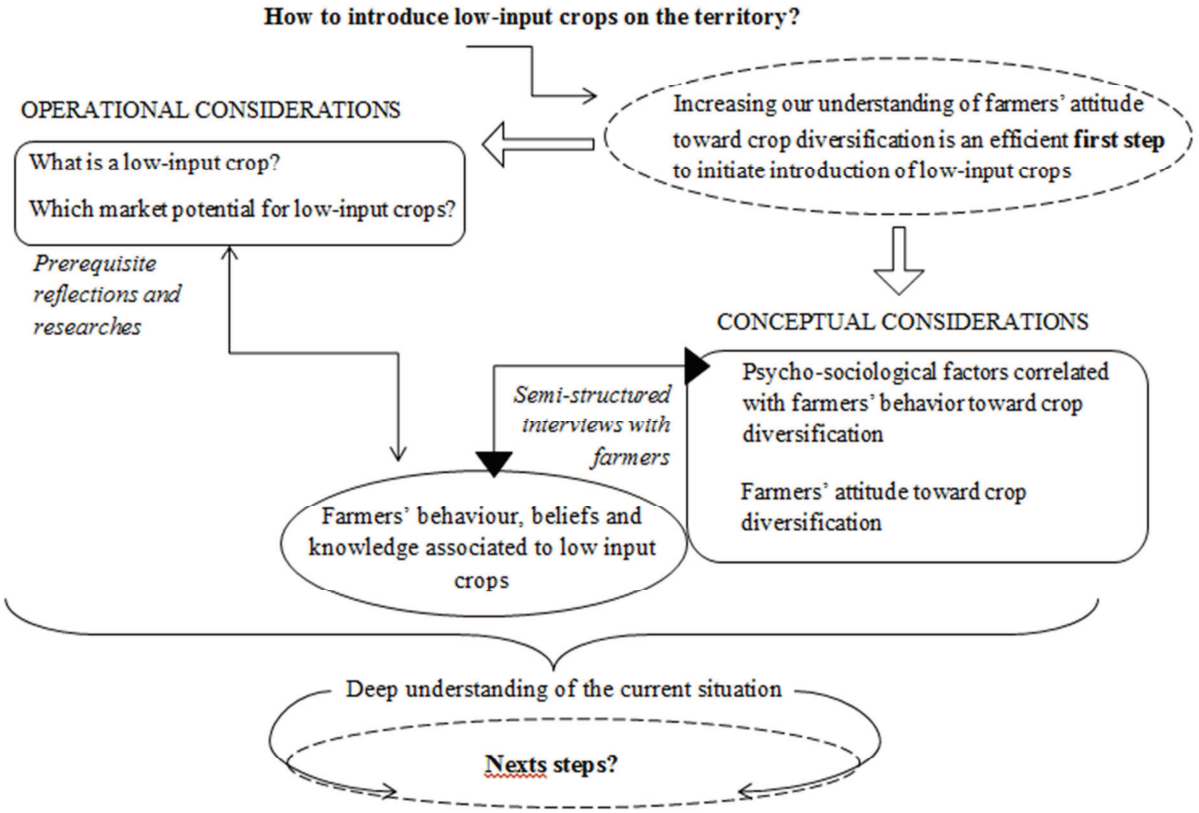


Figure 2 - General overview of the method

[2] Through the whole report, territory refers to Barrois and Pays d'othe natural regions which is the scale of the study

2.2.1. Low-input crops: Input-requirements and marketability

I selected the crops to introduce at the landscape scale according to their requirements in terms of N fertilizer and plant health products. Then, I classified those crops according to their marketability.

2.2.1.1. Defining maximum input requirement

Defining major, intermediate and minor crops

In order to classify crops according to their importance in term of surface (major, intermediate or minor), I aggregated data collected by Vegellia (see appendix 4). This data base is not exhaustive, thus I compared those data to the ones from the "register parcellaire graphique" (can be translated as graphical plot register). This second data base is exhaustive but access is restricted. Comparing the two sources I considered that data from Vegellia were representative enough to serve my objective. Statistics about mean cultivated area devoted to each crop, each year from 2011 to 2013 are presented in table 1.

Table 1 - Territory's arable land occupation (Source: Vegellia 2012 & 2013)

Common name	***Latin name***	**Part of the cultivated area (%) 2011-2013**	**Importance of crop**
Winter wheat	*Triticum aestivum*	37,8%	Major
Rapeseed	*Brassica napus*	28,5%	Major
Winter barley	*Hordeum vulgar*	19,1%	Major
Spring barley	*Hordeum vulgar*	8,5%	Intermediate
Sunflower	*Helianthus annuus*	1,9%	Minor
Winter pea	*Pisum sativum*	1,4%	Minor
Corn	*Zea mays*	1,2%	Minor
Spring pea	*Pisum sativum*	1,0%	Minor
Hemp	*Canabis sativa*	0,5%	Minor
Lentil	*Lens culinaris*	0,2%	Minor
Beetroot	*Beta vulgaris*	0,0%	Minor

Describing management practices

The two main pollutants found in the water being nitrogen and plant health products (see 2.1.3), I chose to fix the maximum requirements on those pollutants. To define those maximums, I analyzed current nitrogen fertilization and pesticides consumption for both major and intermediate crops. As presented in table 2, spring barley requires less input than each of the three other crops. In order to lower the risk that crop diversification increases input consumption, I decided to select crops that require less nitrogen and/or less plant health products than spring barley.

Table 2 - Selected crops' management practices (Treatment Frequency Index (TFI) is a pesticide consumption index (Brunet et al, 2008))

Common name	*Latin name*	TFI 2012-2013	Nitrogen use (kg of N per hectare) 2011-2013
Winter wheat	*Triticum aestivum*	5,0	190
Rapeseed	*Brassica napus*	7,9	198
Winter barley	*Hordeum vulgar*	4,2	153
Spring barley	*Hordeum vulgar*	2,7	132

2.2.1.2. Crops' classification according to input requirements

First list

I drew a first list of crops that were thought to consume fewer inputs than spring barley (see table 1 of appendix 5). Those crops were selected according to two criterions:

- Having already been observed in the region and potentially low input
- Quoted in the literature dealing with input efficient cropping systems

Data collection

In order to gather both objective and locally reliable information on management practices observed for those crops I used multiple sources: internal experts (local advisors working on the territory), external experts (consultants working on other territories), local data (Vegellia) and literature.

The information gathered for each crop was soil and climate conditions requirements, N fertilizer and crop protection requirements and expected yields. The interviewees were asked to answer in units of the selected criteria. When this was not possible, they were asked to answer in terms of smaller or greater than the maximum requirement (see table 2&3 of appendix 5).

Synthetizing data

The different answers were not always homogeneous thus I kept the mean answer for each crop and each criterion. For example if two sources stated that N fertilizer requirement of crop X was smaller than N fertilizer requirement of spring barley and one source stated the opposite, I kept the first statement. Considering amount and homogeneity of answers I classified the crops regarding to the reliability of the mean answer (see tables 3 to 5). Finally, I chose to keep each crop from table 3 and 4 for both market and farmers' surveys (see table 4 of appendix 5 the crop that I did not keep).

For table 3 and 4:
***Reliability*: 1 = no divergent data and at least two data per criterion; 1.1 = no divergent data but only one data for at least one of the criterions; 2 = divergent data for one criterion and at least two data per criterion; 2.2 = divergent data for one criterion but only one data for at least one of the criterions; * = local (territory or department scale) data from Vegellia**
***TFI*: (<) = crop requires less treatments than spring barley; (<=) = crop requires less or as much treatments as spring barley; (>) = crop requires more treatments than spring barley; (>=) = crop requires more or as much treatments as spring barley; (?) = no information**
***Data*: total number of answers for this criterion**
***N fertilizer*: (<) = crop requires less N fertilizer than spring barley; (<=) = crop requires less or as much N fertilizer as spring barley; (>) = crop requires more N fertilizer than spring barley; (?) no information**

Table 3 - Crops requiring less N fertilizer AND less plant health products than spring barley

Common name	*Latin name*	Reliability	TFI	Data	N fertilizer	Data
Spring oak	*Avena sativa*	1	<	3	<	5
Afalfa	*Medicago sativa*	1	<	5	<	5
Pearl Millet	*Pennisetum glaucum*	1	<	5	<	2
Lacy phacelia	*Phacelia tanacetifolia*	1	<	3	<	1
Common sainfoin	*Onobrychis viciifolia*	1	<	2	<	3
Buckwheat	*Fagopyrum esculentum*	1	<	2	<	2
Sorghum	*Sorghum bicolor*	1	<	4	<	1
Sunflower	*Helianthus annuus*	1*	<	2	<	4
Soja	*Glycine max*	1.1	<	2	<	3
Hemp	*Canabis sativa*	2*	<	5	=	5
Cocksfoot grasses	*Dactylis*	2	=	4	<=	4
Spring oilseed flax	*Linum usitatissimum*	2	<=	5	<	3
Winter pea	*Pisum sativum*	2.1*	=	4	<	3

Table 4 - Crops requiring less N fertilizer or less plant health products than spring barley

Crop	*Latin name*	Reliability	TFI	Data	N fertilizer	Data
Spring broad bean	*Vicia faba*	1	>	4	<	5
Winter broad bean	*Vicia faba*	1	>	3	<	3
Lentil*	*Lens culinaris*	1*	> (4)	4	<	4
Winter oilseed flax	*Linum usitatissimum*	1	>	2	<	2
Spring pea*	*Pisum sativum*	1*	> (4,5)	3	<	3
Clover	*Trifolium*	1	>=	2	<	3
Common vetch	*Vicia sativa*	1	>	3	<	2
Fiber flax	*Linum usitatissimum*	1.1	>	1	<	1
Corn*	*Zea mays*	1.1*	<	1	> (263)	1
Winter oak	*Avena sativa*	2	>=	5	<	5
Chick pea	*Cicer arietinum*	2	>=	3	<	4

2.2.1.3. Crops' classification according to marketability

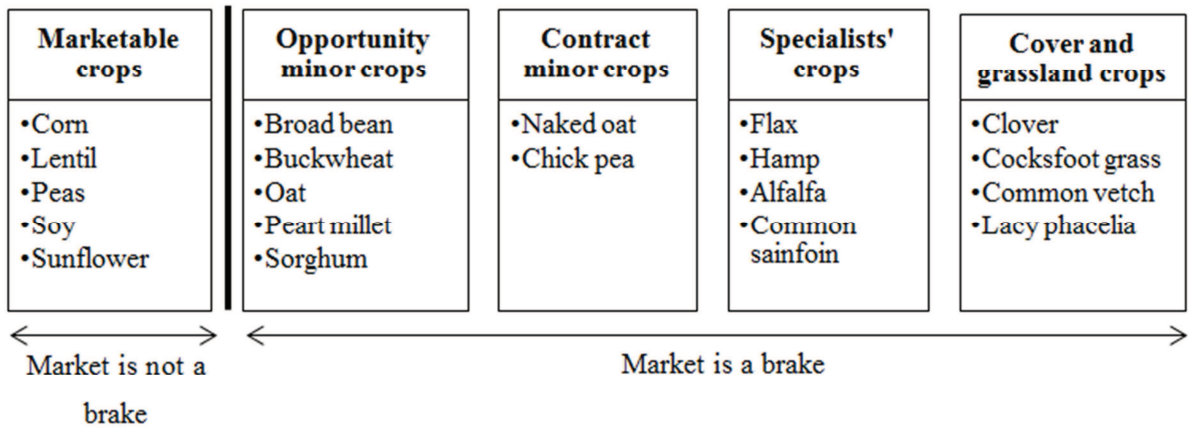
Data collection

In order to identify market issues associated to each of the selected crop I carried out a telephone survey with different structures identified as current or potential buyers for those crops. In order to find those buyers I asked local advisors to identify farmers who produced or used to produce one of the selected crops. In addition, during farmer's interviews (see 2.2.2.), I asked respondents if they knew about actors collecting one of the selected crops. Finally, I asked each actor if they knew about their competitors. I stopped the survey when I had contacted at least two actors of different scopes for each crop.

Classification of selected crops

From buyers' statements, I was able to categorize crops according to their market potential (see figure 3 and appendix 6).

Figure 3 - Marketability of low-input crops



The five *marketable crops* were described by market actors as "not presenting market potential issues". According to buyers, farmers' reluctance for those crops is either linked to price or yields. Thus, focus on new markets for those crops could bring to light more remunerative solutions. Concerning peas, I can suggest deeper investigation on pea production for starch extraction and international market of split pea. For the lentil, there is an emerging market for quality products focused on specific varieties of lentils named "lentils for champagne". The development progress of this quality label appears controversial. However, it could be interesting to further investigate the real development potential of this sector on the territory. Concerning soy, quality sector comes again as the main development potential. Indeed, if processing plants were built in France, French producer could benefit from existing quality market such as "without GMO" or "product of France".

For all the other crops, marketability is a brake hindering introduction on the territory. According to different actors, requirements and opportunities, I drew four other categories. The first five crops are qualified as *opportunity minor crops* in the sense that it is marketed on an "open market". By open market I insinuate that different buyers accept the crop without requiring contract agreement. Within this category markets for Pearl millet and Sorghum seem to be more restricted than others. The *contract minor crops* are commercialized by few or one actor (which is not specific) with contract agreement requirements. *Specialist's crops* are commercialized by one specific actor each. The difference with contract minor crops is that the buyer market only products of this specific crop. Concerning market potential, this exclusivity makes it difficult to get information. Indeed, actors who own the market fear that divulgation of information could lead other actors to position themselves on the market. By contrast with specialists' crops, the *cover and grassland crops* can be commercialized by different actors but market is restricted to cover crops and grassland renewal.

General issues with minor crops

As described in the context section (2.2.2.) two main actors dominate agricultural market on the territory. One of them is perceived by smaller actors as a strong competitor. During the past few years, many small actors merged one with the others or one with larger actors. One of the strategies to avoid merging was to focus on minor markets that large scale actors were not able or not willing to fill. Two difficulties were highlighted about minor markets: calibrate actors' needs in order to adapt production (heard in interview and highlighted by Meynard et al, 2013) and shortfall induced by small volume of crops stocked in buyers' silos. Thus, buyers either provide a truck that has to be entirely (in general 30 tons) and quickly filled or require farmers to stock the product on farm. Concerning business strategy of large scale actors while it is focused main crops, they expressed an interest for diversification focused on marketable crops. In parallel, they conduct some researches about energy crop. Finally, the lack of transparency in buyers' discourse hinder diversification program. It might come from a fear that the competitor "steals the idea" and this competitive environment is one of the major brakes that can be identified at the territory scale. This lack of communication between different actors and different production zones had already been highlighted by Meynard et al in 2013.

2.2.2. Exploring farmers' attitude toward diversification

2.2.2.1. Semi-structured interviews with a diversified sample

Following the initial objective of getting an accurate understanding of farmers' feelings, beliefs and intentions, I needed to gather both verbal and non-verbal information (Streubert et Carpenter, 1995 quoted by MacDonald, 2012). Concerning verbal information, I was seeking for complete

responses with enough detail and depth including farmers' behavior and affects toward their peers. Finally I wanted to use a generalizable method rather than generate generalizable information. Reading a training manual focused on methods for qualitative data collection (Harrell and Bradley, 2009) it appeared pertinent regarding my expectations to conduct semi-structures interviews one-on-one with farmers.

By maximizing the diversity of situations encountered in the sample I aspired to increase the richness of the data collected. Thus I selected farmers according to three criterions allowing me to gather information about different sub populations:

- Current observed behavior toward crop diversification
- Geographical location on the territory
- Membership in a GDA

Those criterions were orally explained to the four GDA advisors working on the territory who were asked to give as many names as possible in each cluster.

Concerning behavioral criterion, allowing me to verify the assumption that farmers' behavior toward diversification can be explained by structural and psycho-social characteristics (see part 3.1.), I chose to classify farmers into three classes:

- Farmers that have a diversified farm: they do not cultivate only major or intermediate crops (at least for the three past cropping seasons, the current one included). This situation was chosen in order to understand reasons leading farmers to start and continue diversification.
- Farmers that have a potentially diversified farm: they are (for maximum three cropping seasons, the current one included) or they are planning to (the next season) to cultivate a crop that is neither major nor intermediate. They were chosen to understand reasons for farmer to start or stop diversification.
- Farmers that have no diversification on farm: they cultivate only major or intermediate crops for at least three cropping seasons. They were chosen to understand what makes crop diversification worse than their current rotation.

In general, I chose to exclude breeders who are introducing a minor crop with the objective of feeding the cattle with it. The ones that introduce a crop and market it were eligible.

Regarding to the location of farmers on the studied area, I tried to cover the territory as completely as possible. With this criterion, I wanted to be sure that the location on the territory had no impact on diversification. Thus I selected farmers from the four GDA of the territory (see map in appendix 7 for the division of the territory used). Finally, I chose to interview both GDA members and non-members to introduce a minimum diversity in agricultural information networks.

When multiple names were given by an advisor, a random number was assigned to each of them. Then, the numbers were and the first farmer of the list was called and interviewed if he accepted. If the first farmer of the list did not accept, the second one was called and so on. When I was not able to meet any farmer in one of the categories, I classified the criterions and met multiple farmers from others categories. The first criterion that was set-aside was the localization. I preferred to meet farmers who have different cropping system in the same location than different farmers who have the same cropping system in different location. Concerning the membership in a Group for Agricultural Development, the criterion was set aside by itself because of a restricted number of farmers belonging to the 'no-member' list. Finally, I met a total of twenty farmers (see categories in table 6). However, one interview could not be exploited at all and one was partially exploited.

To schedule the interviews, interviewers contacted farmer by telephone. The research was presented to the respondent and I asked him to be available two hours in a quiet place. Each interview lasted from forty five minutes to two hours and thirty minutes. Mean lengths was around one and a half hour. Interviews took place in farmers' place, they all had enough available and nothing disturbed the conversations.

2.2.2.1.1. Importance of the interview guide

The interview guide had three parts. The first part focused on the farm and the farmer via "grand tour" questions. For the second part, focus was on crops and crop diversification. Structural questions about the current cropping system and each crop that had already been cropped were asked. All along the interview, structural questions such as "*how did you decide*"; "*who took the decision*"; "*where did you get this information*" were asked. The answer served the third and last part of the interview which focused on agricultural information network.

The objective of the first part was both getting a global understanding of the farm and the farmer and confidence-building in order to create an atmosphere that stimulates communication. Descriptive questions asked included "*Can you give an overview of your farm* (showing scheme in appendix 8)? *Could you tell me the history of the farm, major changes and objectives guiding those changes?*". With the second part I wanted to know actions and intentions of farmer toward diversification. Then, general questions about diversification were asked. In general, the first was: "*could you please give me five words or reflections that first come to your mind when dealing with crop diversification*". With those questions I wanted to highlight affective aspects: I wanted the farmer to give me his feelings about crop diversification. Cognitive aspects were also expected to come out from the overall second part. Finally, the semi-structured interview was used as a "name generator". Each time the interviewee mentioned a source of information, I wrote it. Thus, the third and last part of the guide focused on agricultural information network through questions like: "*Who is influencing you*

when you have to take a decision on the farm?". In some cases I provided the farmer with a target for him to position his sources of information from the closest to the furthest one.

2.2.2.2. Data collection and analysis

2.2.2.2.1. General overview of interviews

One interviewer carried out each interview on his own. Because one person can hardly conduct the interview and capture all information at the same time I decided to record each interview (Harrell and Bradley, 2009). This method provided a good flow to the interview by allowing interviewer to focus on respondent's answers and new questions or probes. Moreover, it allowed getting a nearly exhaustive collection of data. In two situations, I did not get the consent of the respondent, thus, all but two interviews were entirely recorded. In order to avoid any "technical issue" and capture non-verbal information notes were also taken during the interviews. Finally, at the end of each interview I took notes about the feeling of the interviewer or some unexpected things that happened.

As first step for data analysis, I fully transcribed three records. Farmer n°1, n°2 and n°5 were selected because each of them belongs to a different diversification category. With those transcripts, I wanted to find expected or unexpected topic addressed during the interview. In this objective, I read through the interviews and highlighted each topic with a different color. At the end, I had a list of themes and subthemes for each interview transcribed. When the three were transcribed and analyzed, the themes found were compared in order to highlight convergences and divergences. I acknowledged that all themes were not addressed through this limited number of interviews but I observed a sufficient degree of convergences to create an analysis grid. This grid presented six themes and subthemes (see table 5). The next step consisted in the listening of the other records in order to transcribe each interview following the grid of analysis. Thus, the exhaustiveness of themes presents in the grid condition the quality of transcription of the others interviews.

Table 5 – Grid of analysis (with exampled from interview with farmer n°2)

Theme	Subtheme	Farmer n°*2*
Farming	History	*1984 – Farmer joins his brother and father on family farm* …
	Description of the current situation	*220ha of cereals on two villages* …
	Reasoning and vision of activities	*Today I'm satisfied, I have good margins, good yield.* …
	Vision of agriculture in general	*There is so much speculation that it's hard to manage* …
Crop diversification	Knowledge and prior experience	*I stopped broad bean because margin are lower than rapeseeds'* …
	Vision of diversification	*It will modify my organization* …
	Thought about low input crop list	*Some farmers tried flax but stopped* …
Agricultural information network		*If I have a problem I will not rely on other farmers' advices.* …

2.2.2.2.2. Redesign information to allow comparison

Transcription through grid of analysis allowed a deep understanding of farmers' attitude one by one. However, this kind of information is too wordy to be comparable. The second step of the analysis consisted in coding redundant information found among interviews' themes and subthemes. Two types of data were sorted. First the attribute information such as surface and other activities were identified. Then, substantive information was coded. Working with substantive information can fall into subjective points of view. To limit this bias, a session with co-workers from Chamber of Agriculture and MAPC was settled. During this meeting, precise definitions of codes were given to the co-workers. As soon as one researcher had a doubt on the meaning of a code or the difference between two codes, it was replaced. Finally, I always preferred having a missing data than a wrong one. The last step consisted of finding links between behavior toward diversification and any other

theme including agricultural information network through the last table of analysis. In this objective, table showing farmers and codes was built and analyzed (see tables 7 to 11 extracts of the overall table)

3. Results and discussion

3.1. Verification of behavior theory

3.1.1. Four distinct behavior toward crop diversification

Among the three levels of diversification chosen, "potentially diversified" category was less precisely defined than the others. As a result advisors usually struggled in listing farmers from this category, even more when they had no membership in GDA. Thus, while the two "extreme" levels of diversification remained unchanged the intermediate one was split after analysis (see table 6).

Table 6 - Farmers interviewed according to initial and final categories
(Initial categories: D: Diversified, PD: Potentially diversified, ND: Not diversified – Final categories: type of behaviors from 0 to 3, see description 3.1.1 – Each number of the table correspond to a farmer, from farmer n°1 to farmer n°20, farmer n°16 excluded; bold and italic numbers show farmers which does not belong to the same initial and final categories)

	Initial categories					**Final categories**			
	Pays d'othe	**Barrois centre**	**Barrois Sud**	**Barrois Nord**		**Pays d'othe**	**Barrois centre**	**Barrois Sud**	**Barrois Nord**
	Membership in GDA								
D	5	9	3	11, 18	**B3**	5	9	3	
PD	12	2	4		**B2**		2, ***15***	***6***	***18***
					B1			4	***20***
ND	8	15	6	20	**B0**	8, ***12***			***11***
	No membership in GDA								
D	7		10, 19	17	**B3**	7		10, 19	17
PD					**B2**				
					B1			***14***	
ND	13	1	14		**B0**	13	1		

The "diversified (D)" level remained unchanged and will be referred as type 3 behavior (B3) in the following sections.

The "potentially diversified (PD)" level was split in two distinct behaviors:

- The first (B1) represent farmer who are punctually introducing new crops but do not expressed the willingness to ensure the continued presence of one of this crops
- The second (B2) gather farmers who introduced either last year or this year a new crop or planned to introduce next year a crop with the objective of maintaining the crop on a long term period.

The “not diversified (ND)” level remained unchanged and will be referred as type 0 behavior (B0) in the following sections.

3.1.2. Structural characteristics

The farmers I met were cultivating surfaces ranging from 70ha to 310ha. Synthetizing data I found a median value around 150ha (see table 7). Analyzing one by one the different behavioral categories, I highlighted differences:

- The smallest farms of the study (70 and 85ha) both belong to B0
- B3 category presents both the two widest farms (276 and 310ha) and the highest diversity in terms of farm size (from 108 to 310ha).
- Most of the farms which belong to B1 and B2 have a median size (150ha).

From those data, it appears that cultivating more than 150 hectares is more favorable to diversification than cultivating less than 100ha. Farmer n°12 (70ha) even emphasized “*in order to diversify, first need would be to get new land*” and explained that diversifying on 70ha raises logistical issues. At first sight, the wide range of different farm size in B3 category invalidates this statement. However, a detailed analysis of farms n°3, n°10 and n°19 which are the smallest B3 farms (respectively 117, 108 and 130ha) highlights specific characteristics. Farmer n°10 who exposed his enthusiasm toward agriculture and more precisely direct seeding is devoted to agriculture. However, he insisted on the difficulty of having such diversity on a small farm. While I observed the same devotion to agriculture interviewing farmer n°3, he assumes that if he accepts the risk induced by diversification it is thanks to the profitability of the vineyard. Farmer n°19 has drainage systems in some fields which forced him to replace rapeseed by sunflower in those plots. Moreover he shared his willingness to introduce another crop to decrease his dependency on feed suppliers. Finally, farmer n°9 who is a breeder as well (but a widest farm: 170ha) stated that he would not take the risk induced by diversification if he was not able to ensure a value to his crop by feeding his cattle with it. From those results it appears that diversification is perceived as a risk that is decreased by other sources of incomes and/or increased farm size. The “*positive relationship between diversification and size*” was also highlighted by Pope and Prescott (1980). However, as raised in 2.1.2., mean farm size in the department is 143 hectares. Thus, most of the farms of the territory present good structural potential for crop diversification. Finally, a link between crop diversification and risk emerged in this part and will be further investigated by the analysis of farmers’ marketing strategies.

Concerning the other productions, while farmer-winegrower n°3 takes more risk thanks to his vineyard, there is no general trend linking crop diversification and winegrowing. Growing grape can even have a contrasted effect on the ability to diversify. On one hand, it ensures a stable income to the farmer. On the other hand, tasks in the field can overlap with tasks in the vineyard. For example,

many grape growers complained that sunflower harvest overlap with grape harvest. For two of them it is the first brake to sunflower introduction on their farm. In general it appears that grape growers-farmers tend to prioritize tasks in the vineyard compared to any other task. By contrast, even if I only met two breeders I can assume that cattle production has positive impact on crop diversification.

Table 7 - Structural information about farms
(n° refer to the number that was given to each farmer to anonymize data; Div. refers to farmer's behavioral class (see 3.1.1.))

n°	Div.	Farm total surface, hectare	Other productions on farm	Membership in GDA
1	B0	260	vineyard	
8	B0	100		Yes
11	B0	145		Yes
12	B0	70		Yes
13	B0	85		
4	B1	150	vineyard	Yes
14	B1	260		
20	B1	130		Yes
2	B2	220	vineyard	Yes
6	B2	140		Yes
15	B2	150		Yes
18	B2	151	vineyard	Yes
3	B3	117	vineyard	Yes
5	B3	276		Yes
7	B3	310		
9	B3	170	Cattle	Yes
10	B3	108		
17	B3	250		
19	B3	130	Cattle	

Because of both misconception of farmers behavior from advisor and (see table 6) and impossibility to schedule interview with farmers from each initial category the sample was too small and not enough homogeneous to allow investigating the potential links between the type and behavior and geographical localization and membership in a GDA. Advisors' misconceptions stress out a lake of information of advisors concerning farmers' behavior.

3.1.3. Marketing strategies and risk aversion

While development of cooperatives gave farmers the opportunity to delegate both stocking and marketing strategies some of them are getting involved again in the marketing strategy. Through this part I wanted to investigate the link between farmers' involvement in marketing strategy and their behavior toward diversification.

Table 8 - Marketing strategies
(n° refer to the number that was given to each farmer to anonymize data; Div. refers to farmer's behavioral class (see 3.1.1.); in agreement on prices: "mean" implies that farmer delivers the production while harvesting and gets a mean price calculated by collect actor for the whole season – "contracts" implies that farmer sign a contract for defined quantity, quality and price - "market" implies that farmer sells his production at any price, any time and to any actor.

n°	Div.	Agreement on prices	Works with one of main actors	Number of minor actors involved	Stocks on farm
1	B0	mean	Yes		
8	B0	mean	Yes	1	
11	B0	mean	Yes		
12	B0	mean + contracts	Yes		
13	B0	mean	Yes		
4	B1	mean + market	Yes		
14	B1	market	Yes		Yes
20	B1		Yes		
2	B2	market + contracts	Yes	1	Yes
6	B2	mean	Yes		
15	B2	mean + contracts	Yes		
18	B2	mean + market + contracts	Yes	2	Yes
3	B3	market + contracts	Yes	3	Yes
5	B3	market + contracts		2	Yes
7	B3	contracts + ?	Yes	1	Yes
9	B3	mean	Yes		
10	B3	mean + market	Yes		
17	B3		Yes		
19	B3	mean	Yes		

All but one farmer interviewed is selling part or totality of his production to one of the main actors (see table 8). It confirms their importance on the territory. However, six of them chose to diversify their buyers. While different farmers expressed the willingness to "*sell to the one who gives the best price*", farmer n°5 wants to "*decrease his dependency toward buyers",* farmer n°7 wants main actor to "*react*" and farmer n°18 stated that "*enough is enough*".

General marketing strategy observed with B0 farmers is: mean price to main actors without stock on farm. By contrast the majority of B1, B2 and B3 farmers are more involved in their marketing strategy. Most of them not only sell at mean prince but also at market price or through contracts. Moreover, marketing strategy management and stocks on farms seem to be linked. While farmers n°3, n°5 and n°7 directly linked those facts during the interview "*I invested in storage bins to be able to market my productions on my own*" others gave no details.

This weak involvement in the marketing strategy observed with B0 farmers can be the result of reduced involvement toward agriculture in general or high risk aversion. Indeed, forward contracting

and minimum price contracts are described by Musser et al (1996) as tools to manage price risk. While local institution will hardly change farmers' involvement toward agriculture, they can have impact on their attitude toward "risky situations". Further than local institutions, different actors can influence farmers' behavior. Studying their agricultural information network appeared as an important tool to understand what influence farmers' decision making process.

3.1.4. Agricultural information network

In the following part, after describing the general attitudes that farmers have toward their agricultural information network, I will focus on two points. First I will give a deeper description of farmers' relation with their peers. Then I will investigate the different farmers' behavior toward advisors and/or SSR[3].

3.1.4.1. General overview

As a starting point for network analysis I decided to get a broad overview of farmers' agricultural information network. During the interviews I tried to get an exhaustive list of the sources of information mobilized by farmers through their decision making processes. In this part, I will relate the number and nature of sources with farmers' behavior. At the end of the interview, 12 farmers were asked to position those sources on a target representing the influence that each source has on him. From this exercise I gathered farmers' personal interpretation of their own attitude toward their network. Reading those results, reader has to keep in mind that farmers could have been influenced by the fact that the interviewer introduced himself as member of chamber of agriculture.

In general, by ranking sources of information according to their frequency of occurrences (see table 9) in the interviews I observed that:

- SSR, advisors and peers were mentioned more often than other sources (respectively in 17, 14 and 14 interviews out of 19)
- Magazines and "myself" occurred, respectively, 13 and 12 times
- Internet, family and "other sources[4]" were less often mentioned (7, 4 and 9 farmers respectively).

On average, B1, B2 and B3 farmers quoted one more source compared to B0 farmers. More into details, almost each B3 farmer read agricultural magazines while less than half of the farmers from B0 are doing so. Moreover almost each farmer from B2 and B3 mentioned themselves and their

[3] From the beginning of the report the term advisor is used to designate the manager of GDA. In this section we will introduce another type of consultant: Sales and Service Representative. These SSR work for collect/stock actors. Besides providing the same services as advisor they sell inputs and buy crops. Finally, the term consultant will be used to designate both advisors and SSR.

[4] "other sources" can refer to a wide range of specialists, exhibitions or associations

experience as being an influent element on their farm management. On the contrary only one farmer from B0 and one from B1 said so.

Then, when asked to farmers to classify sources regarding to their influence, B0 and B1 farmers most often ranked SSR or advisor in first or second position. When it was not one of those actors either members of the family or peers were ranked first. Going to B3 farmers, they placed themselves, their family, internet, their peers or other sources of information in top of the list. Thus, they never quoted the SSR or the advisor as being the first or second source of information. By contrast, B2 farmers are not homogenous: while some present characteristics similar to B0 and B1, others are closer to B3.

Table 9 - Overview on agricultural information network
(in each column, Y (yes) means that the farmer mentioned this source of information, 1, 2 or 3 means that the farmer ranked this source of information as being the 1st, the 2nd or the 3rd influential factor on his decision making processes)

n°	Div.	SSR	GDA	Magazines	Peers	Himself	Others	Internet	Family	Total
1	B0	1							1 (father)	2
8	B0	2	1	Y	3					4
11	B0	Y	Y		Y	Y		Y		5
12	B0	1	Y				Y			3
13	B0		2	Y	1		Y	Y		5
4	B1	Y	2	3	1		Y	3		6
14	B1	Y		Y	Y			Y		4
20	B1	3	2	Y	Y	Y			1 (son)	6
2	B2	2	1	Y		Y				4
6	B2	1	2		2	Y		Y	3 (father)	6
15	B2	Y	Y	Y	Y	1	2			6
18	B2	Y	Y		Y					3
3	B3	Y	Y			Y	Y			4
5	B3	4	3	Y	Y	1	Y	2		7
7	B3	Y	Y	Y	2	Y			1 (father)	6
9	B3	Y	Y	Y	Y	Y				5
10	B3			Y		Y	Y	Y		4
17	B3	Y		Y	Y	Y	Y			5
19	B3	3		4	4	1	2			5

In the category of farmers who currently do not and do not wish to diversify, I found persons who are not self-sufficient in terms of farm management. Indeed, not only they did not characterize themselves as being the most influent actor of their own decision making process, but also they strongly rely on external actors: advisors or SSR. Without giving any opinion on advisor or SSR I can see the great confidence in those actors as a weakness. Indeed, Labarthe (2010) emphasized on the existence of inherent locked-in of advisory services. Need for strengthening farmers' experimental capacity and autonomy is also stressed by Sabourin et al. (2004). Finally, I can hypothesize that this lack of self-sufficiency can be either general personal characteristic or linked to

a limited interest toward agriculture. By contrast both the curiosity and the self-sufficiency of farmers from B3 are factors which can partly explain their ability to diversify. Their major strength is that, regardless of the source of information, they form their own opinions of it rather than accepting it as an absolute truth. Just like risk assessment, local institution could work with farmers on their self-sufficiency.

This first overview of agricultural information network included sources of information which do not imply human interactions. Focusing on peers and local consultant supports Rogers (1983) statements on the influence of "human interaction through interpersonal network" on adoption of ideas.

3.1.4.2. Focus on peers

Acknowledging conclusions from Compagnone and Hellec (2014) on the link between farmers' behavior toward others and their dynamic of change, I emphasis on those relations during the interview and the analysis.

Table 10 - Farmers' behavior toward their peers, ***for the definitions of the terms used, see appendix 9***

n°	Div	Behavior toward peers	Function of peers
1	B0	Selective	Compare
8	B0	Restricted passive	Compare
11	B0	Restricted active	Compare
12	B0	Restricted active	Compare
13	B0		
4	B1	Selective	Get specific information
14	B1	Opened passive	See something else
20	B1	Opened active	Compare
2	B2	Opened passive	See something else
6	B2	Selective	Get specific information
15	B2	Opened passive	Get specific information
18	B2	Opened active	Get specific information
3	B3	Opened active	Share
5	B3	Opened passive	See something else
7	B3	Opened active	See something else
9	B3	Opened active	See something else
10	B3	Selective	Share
17	B3	Selective	Get specific information
19	B3	Restricted active	See something else

All farmers from B0 interact with a restricted number of farmers either in an active of a passive way (see table 10). Moreover, the objective of those interactions is to compare their farms to the others'. It can happen that comparison focuses on practices but more often it is only about results. Then, farmers who belong to B1, B2 and B3 have relations with their peers going from the "closest" one (selective) to the most "opened" one (opened active). However, while they behave the same, they do not have the same intentions. Farmers from categories B1 and B2 are often going to their peers in order to get specific information. By contrast, farmers from B3 who do not behave differently give another function to their peers. Indeed, most of the time, when there is an interaction, B3 farmers expect to discover practices that are different from their own practices. Farmer n°20 who belongs to category n°1 presented interesting characteristics. While he behaves like others farmers of B1, B2 and B3: he has an opened active behavior, he gives the same function to his relations with peers as B0 farmers: he compares himself to the others.

Finally, while it appears as an influent factor on attitude toward crop diversification, it is hard to realize whether or not the lack of inclusion observed with B0 farmers is deliberate. Their need to compare their results also impacts their ability to change by creating a competitive dynamic. Indeed, a farming system that changes can be less competitive at the beginning because farmer and component of the system need to adapt to the new management practices. Moreover, comparing yields or number of inputs application does not reflect the whole system and highlight a lack of deep analysis of the overall farming system. However, if I look back to the special case of farmer n°20 I can make the assumption that behavior toward peers is more important than given function. Indeed, having relations with different types of person increases both probability to open their mind to new practices and their "*social capital*" (Meda, 2002). However, when it is intentional to discover new practices (B3) it is even more efficient. Those finding are in accordance with Rogers (1983) considerations on diffusion effect which highlight the influence that "*activation of peer networks about the innovation*" have on innovations' adoption.

3.1.4.3. Focus on local consultancy

As highlighted in part 1.1.2.1., both SSR and local advisors are playing an important role in farmers' decisions. Thus, I decided to emphasis on the different interactions that can occur between farmers and consultants.

First, concerning the form, only four farmers prefer to obtain information through group meetings[5] (see table 11). Indeed, most of the interviewees prefer to call the advisor/ SSR personally or do not feel the need for more information than what they obtain by reading technical notes. The four farmers who favor group meeting belong to B1, B2 and B3. None of the B0 farmers prefer to obtain

[5] See part 2.2.4 descriptions of advisors work. Sales and service representative offer similar services.

information through group meeting. Concerning the function given to advisors or SSR, while B0 farmers have different level of dependency all of them expect advices concerning plant health products. None of them get in touch with advisor or SSR in the objective of changing a component of their farming system. Looking at farmers from B1, B2 and B3 they are not different one another. Many of them use advices to improve their farming system. However, the majority look for specific improvement on specific practices.

Table 11 - Farmers' behavior toward advisors and SSR, ***for the definitions of the terms used, see appendix 9***

n°	Div	Form of advice	Function of the advice
1	B0	Personal	Get prescription
8	B0	Technical note	Reminder
11	B0	Personal	Solve a problem
12	B0	Personal	Get prescription
13	B0		
4	B1	Group meetings	Improve precise practices
14	B1	Personal	Reminder
20	B1	Personal	Reminder
2	B2	Group meetings	Improve in general
6	B2	Personal	Solve a problem
15	B2	Technical note	Improve precise practices
18	B2	Personal	Improve precise practices
3	B3	Personal and Group meetings	Improve in general
5	B3	Personal	Solve a problem
7	B3	Personal	Improve precise practices
9	B3	Personal	Reminder
10	B3		
17	B3	Group meetings	Improve precise practices
19	B3	Technical note and Personal	Reminder

The observation drawn on the personal form of advice chosen by B0 is consistent with the conclusion drawn about the relations they have with their peers. Group meeting can be a way to open the peer network and having an opened peer network can increase probability to participate to group meetings. Concerning all the behavioral categories, it is interesting to observe the wide range of different expectations that farmers have toward the content of the advices given by consultant. It raises concern about the efficiency of the current services offered by consultant. Consultancy through group meetings does not seem to be brought forward by chambers of agriculture (Auriscote et al, 2012). Those observations stress the need for innovation in the form or content of those meetings which offer does not seem to be as diverse as expectations are.

Analyzing structural information, marketing strategies and agricultural information network I could highlight differences between farmers according to their behavior toward crop diversification. First, the size of the farm is a structural factor influencing ability to diversify (3.1.2). Then, crop diversification such as any change in the system can be perceived as a risk which should not be overrated by farmers (3.1.3). Curiosity, critical thinking, open mindness, system thinking and social inclusions are traits shared by farmers who already introduced crop diversity on farm. However, in some cases competitive spirit can inhibit crop diversification (3.1.4).

3.2. Describing attitudes to highlight levers

In this part, information describing the attitude of farmers toward diversification was split into three parts: the positive aspects of diversification; the negative aspects of diversification and farmers' requirements to go to crop diversification. A better understanding of farmers' attitude toward diversification appears as a key to better targeting information given to farmers (Barnes et al, 2011).

Farmers' disposition to respond favorably to diversification

All but one farmer who do not diversify believe that diversification has an impact on **weed management**. While two of them stated that it improves weed management in general, two others feel that they would both decrease herbicide use and be able to apply a wider range of herbicide molecules if they integrate new crops. One of them emphasized that it would **decrease rapeseed proportion** in the rotation without giving more information. Finally, a farmer quoted a **positive rotational effect**. However, it was focused on leguminous crop and their interest in nitrogen input in the rotation.

Statements related to weed management highlighted in B0 category appears as well in conversations with farmers B1. Further than herbicides, farmers from B1 quoted a **decreased use of other inputs** such as fertilizers. Two of them highlighted **agronomical advantages** "*It mimics natural mechanisms*" and "*it has a positive impact on soil quality*". Finally, one insisted on **economic aspects** "*it decreases dependency toward buyers*"; "*with such low prices of cereals we will not have other choice than diversifying*".

Weed management improvement (but nothing about herbicide), decreased rapeseed proportion and positive agronomic impact were also raised by farmers from B2. By contrast, one of them attributed to crop diversification an advantage that neither B0 nor B1 farmers raised: "*the introduction of new crop **staggers the workload***".

Each positive aspect associated to weed management quoted by B0, B1 and B2 farmers was also highlighted by B3 farmers. However, by contrast with the other behavioral categories, more

importance was given by those farmers to agronomic improvement associated with crop diversification. Indeed, statements like "*It has a positive impact on biodiversity*"; "*It has a positive impact on soil quality*" or "*leguminous crops bring nitrogen to the system*" were often heard during interviews. Emphasis was also made on the positive aspect of workload distribution over the year. Moreover, other arguments such as "*diversification* ***spreads the risk***" or "*it could be an* ***alternative to yield cap***" were raised. Finally, two farmers spontaneously highlighted their **personal interest** in crop diversification.

Farmers' disposition to respond unfavorably to diversification

First argument was on **local soil and climate conditions**: three farmers from B0, each B1 farmer and three farmers from B2 complained about the absence of crop that suit to local conditions. However, B3 farmers do not share this opinion. Other negative opinions were punctually raised by B0 farmers: "*It is more complicated*"; "*I am too old to consider such change*"; "*It would require to find new marketing solutions*"; "*It would require to invest in new equipment*"; "*It would increase the workload and tasks would overlap with working period in the vineyard*"; "*It would change my habits*"; '*It would require me to acquire new knowledge*". I see here that most negative aspects are associated with the **changes induced by novelty** in general (complication, changing habits, and new knowledge).

Further than soil and climate conditions, B1 farmers agreed on the **commercial aspects** such as "l*ack of buyers*" or need for new marketing solution. Moreover farmern°4 expressed his skepticism about the **profitability of diversification**: "*it is hard to see further than the annual gross margin*" or "*it is not obviously profitable*". Finally farmer n°20 pointed out the **fragmentation of plots** with a great distance between plots and from farm to plots

Concerning B2 farmers, they focused on **logistical complications**, tasks overlapping / changes in working period, needs for new marketing solution and **new equipment** and absence of economic advantage ("*apparently no economic advantage*"; "*decreased annual gross margin*").

Finally, even if they diversify B3 farmers acknowledge that there are negative aspects associated to crop diversification. Firsts concerns were on the **increased workload** that it represents and the need for new equipment. Then other issues were pointed out without any convergent opinion among farmers from the category. For example, they pointed out the **need to reflect on new practices** which are more complicated and thus time consuming. Moreover, lack of buyers and **peers negative experiences** were also quoted.

Farmers' requirements for diversification

Concerning requirements, two farmers from B0 category stressed the need for both **efficiency and profitability**. For them to go to a new crop, it has to be at least as profitable as rapeseed and suits to a consequent number of plots for logistical and financial considerations. Two others agreed on the **need for peers to try before and succeed**. **Expectations toward cooperative** were expressed by two of them. One stated that he wishes "*that cooperative propose a crop that suits to local soil and climate conditions*". The other affirmed that he would not start with a new crop if it would imply to sell it via another actor.

Further than the need for profitability and the need for others to succeed before, different levers were raised by farmers from B1 category. A**gronomic considerations** appeared: "*if the buyers would accept that I sell a mix of different crops*" (referring to mixing leguminous crops and cereals) or "*if living mulch is considered as diversification*" (referring to conservation agriculture principles). Others concerns such as a need for **proven beneficial effect**, or the need to **face agronomic issue** before implementing new practices were quoted.

Only two levers where highlighted by B2 farmers: **forced by the law** or face an agronomic issue.

Concerning diversified farms, for the ones who have two activities on the farm (crop/cattle or crop/vineyard) the second activity was pointed out as a lever for diversification. For cattle producers, the need for a **crop that can be used for feeding the cattle** was a basic requirement. For the winegrower, **incomes from the vineyard** were necessary to undertake the risk induced by crop diversification. Finally, one of them who orient his whole cropping system toward **direct seeding** stated that this practice is the first lever and first brake to crop diversification. Indeed, diversification is needed for direct seeding system to be sustainable but not all crops suits to such technique.

General analysis

Those observations show that brakes and levers can be highlighted at different scales depending on the behavioral category. While B0 farmers assess the plot scale (soil and climate situation; weed management improvement) the others both share those considerations and see further. First, B1 farmers think about the marketing strategy (lack of marketing possibilities; decreased dependency toward buyers). Then, B2 and B3 farmers raised concerns on impacts at the system scale (respectively need for different organization; staggered workload and increased workload; risk spread). Those differences can be linked to the level of knowledge that those farmers have about diversification. Indeed, B0 farmers who never experienced diversification, fear "basic issues" such as soil and climate conditions, need for new knowledge… by contrast, B1, B2 and B3 farmers, who are more experienced, highlighted operational issues. Finally, when interviewing B3

farmers I could feel that the increased workload is not anymore an issue but a component that has to be accounted.

Moreover, there is a different approach to crop diversification depending on behavioral category and the corresponding knowledge. When B0 farmers deal with crop diversification they consider introducing a new crop between the others. By contrast, the other farmers interpret diversification as an improvement of the overall cropping system. For B1 farmers, they feel the need to create a new cropping system, for B3 farmers, they have considerations further than the cropping system. As both a consequence and a proof for required systemic approach, B0 farmers present weak agronomic considerations in general. By contrast, I feel an increased focus on agronomy in interview with B1 and B2 farmer. This importance is even more evident when interviewing B3 farmers. One example is the behavior toward rapeseed. B0 farmers want to have a crop that is as profitable as rapeseed and they acknowledge that a new crop could lower input use. However they do not link that information and thus do not acknowledge the cost saving potential associated to decreased input use.

Between farmers who already started to diversify (B1, B2 and B3) there are no strong differences but some nuances. Farmers from B1 appear more interested in diversification than farmers who belong to B2 even if the second ones expressed the willingness to lastingly introduce a new crop in their system. Indeed, unlike B1 farmers, B2 farmers express more negative opinions compared to positive ones. Here I come back to the link between attitude and knowledge. While B1 farmer are not building a strategy of sustainable diversification, they know more about it than B2 farmers. Thus, they overpassed some fears that B2 farmers still have such as the working period or the commercialization. Moreover there is a difference between the behavior of B2 farmers and their attitude. While they state that they will not diversify before facing agronomic issue or being forced by the law, they currently consider diversifying “as a precaution”.

In a first time I described convergences and divergences observed between behavioral categories about farms, farmers’ personality and attitude toward their network. Then I described the different attitudes that farmers have when dealing with crop diversification. Those results are expected to help guiding farmer toward crop diversification. However, other criterions that I did not consider before emerged during the interview. First, the main personality traits of farmers influence their way of managing the whole system. Moreover, being a farmer implies: being an agronomist, being a machinist, being a manager, being a trader…this accumulation of tasks in the same professions often implies that the farmer has a preference for one. The following theory that emerged through the analysis is based on those two characteristics.

3.3. Generation of priority management theory

From conclusions drawn through the previous section and overall interviews, different sociological types of farmers could be defined according to their main personality trait or their favorite aspect of farming (see figure 4). This "*grounded theory*" was discovered from data (Glaser and Strauss, 1999) unlike the previous behavioral theory that was tested. Those categories were drawn to give insight for further investigation and suggestions for improvement should be taken as examples not as replicable and generalizable results (Arévalo and Ljung, 2006).

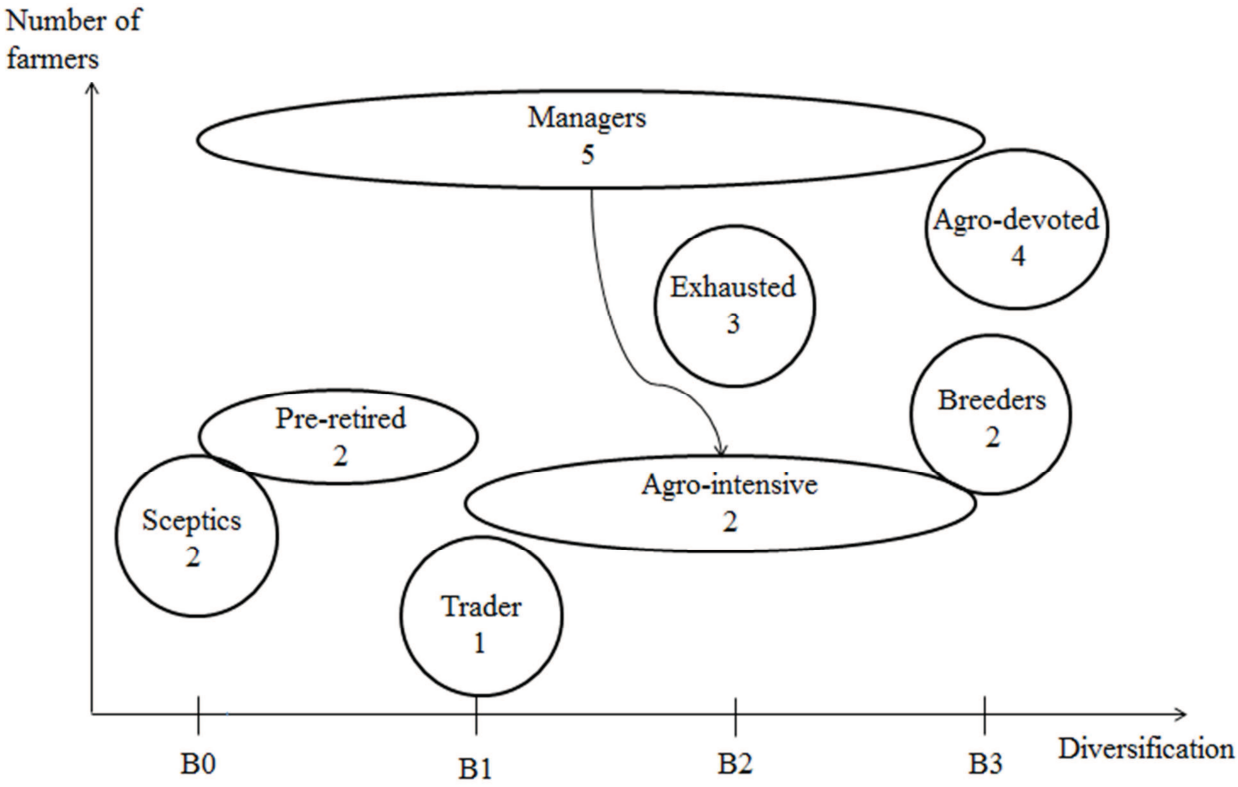


Figure 4 - Classification of farmers according to crop diversification and priority management (in the bubbles: title of priority management, number of farmer in this category; the arrow between managers and agro-intensive shows that the two agro-intensive are also part of manager category)

Sceptics

As raised in appendix 10, farmers n°8 and n°12 are sceptics and not self-confident enough to undertake any change on farm without having the proof that it works. Their skepticism is oriented toward anything and anyone "*I have two friends, one is a trickster*" (farmer n°12); "*I could join a buying group, but you need to be confident*" (farmer n°8). Farmer n°12 recently took over the farm and has little knowledge about agriculture. Farmer n°8 is more experienced but not self-confident enough to decide by himself management practices. Hence, for those farmers to change their system, they have to be reinsured either by learning from the others or by learning from a consultant. For them to take their own way, they need long term individual supervision.

Pre-retired

Farmers 13 and 20 are close to retire. It is understandable by talking with them that they are not willing to undertake changes by themselves: "*I am not part of any group because I am too old*" (farmern°20) "*I chose simplicity in relation with my age but I when I will delegate the work I might think further*" (farmer n°13). Both have an idea of what will be next. They know who will run the farm and can consider giving directions to this person about changes they would like to see. Focus should be made on the person who will take over the farm. Their interest can be caught by new practices but the future farmer will have to agree on it. Before working with those farmers toward change, consultant need both to know who will take over the farm and the influence that farmer has on his successor. Indeed, if the son continues, the farmer can have a certain influence that he will not have if a contractor takes over the farm.

Trader

Farmer 14 is so independent that he hardly listens to advices from the other. When he changes something in his system, he does the trials himself. However he showed a particular interest for trading. He is the only one who markets the entire production at market price. It is an interesting kind of farmer when dealing with diversification thanks to his ability to market on his own. However for him to change he has to find interest in new practices. It is hard to predict his actions but creating a stimulating environment around him appears to be the best way to attract his interest to new practices.

Exhausted

Farmers 2, 15 and 18 have similar behavior. They are thinking about potential improvements but they do not realize much because they are tired, less dynamic than they used to be. Those farmers are interesting because they know a lot and they have still a potential for change. In order to catch their attention on new practices, focus has to be made on the easiness and short term impact of those changes. By easiness I first deal with the need for financial investment that has to be low as well as the need for knowledge. The required knowledge does not have to be too deep and time consuming for them to accept the change.

Managers

Farmers 1, 4, 6, 11 and 17 share the objective of having a cropping system which is profitable and efficient (see appendix 10). Their primary interest is on management. I come to this conclusions by criterions quoted for new crop introduction: on an important part of the farm for economic and logistic reasons and profitable. In general, agronomy is not their first interest in farming. For

example, farmer 1 is an agricultural machinery enthusiast. Concerning farmer 11 and 6, they are busy with their service delivery. Indeed, they spend as much time on others' farms than on their own farms. Farmer 11 even stated that he "*prefers service delivery than the profession by itself*". It is the testimony of an interest for working in the fields more than reflecting on cropping practices. In order to catch the interest of those farmers, the new practice or the impact of the introduction of new crops has to be assessed in details. Those details have to be focused on time and financial costs of such change. If they do not find interest in this assessment, they will not change the system without being forced to.

Agro-intensive

Farmers-managers 4 and 17 share another dominant characteristic: they make use of agronomy to serve efficiency. Indeed, they have cropping systems oriented toward direct seeding or even conservation agriculture because it saves times not to plough. Thus, any change in the cropping system will serve direct seeding needs and will have to be efficient and profitable. This second characteristic makes it even harder to raise their interest in a practice.

Agro-devoted

Farmers 3, 5, 7 and 10 each manifest a strong interest toward agronomy. For example, when dealing with crop diversification, two of them answered that they find a "personal interest" in trying new crops, introducing new practices. Their profession is a passion and they are always looking for new information, new concept. Great effort has to be made to reach their interest because of their high knowledge level. Indeed, they are often ahead of their time and demand information on the latest improvements that are sometimes not yet implemented in their own country.

Breeders

Farmers 9 and 19 are both farmers and breeders. In the two cases, most of their time and interest is going to breeding, not to cropping. Thus, if any change is undertaken in their cropping system it has to have no impact on time available for cattle. The first limiting factor is on consultant specialty which is either on agronomy or on zootechnics. Indeed, those farmers have information from two groups, a breeder group and an agriculture group and they have to rely on their own capacities to link knowledge.

Farmers whose system is too much focused and defined are hardly reachable. The novelty has to fulfill many requirements to be adopted. The first brake is to be able to demonstrate those

requirements the second is that a novelty hardly meet each of their goals. What I highlight here is the different possibilities that are offered by farmer for introducing changes on the territory. They are often opened to suggestions as soon as it is formulated in their own words. Reinsuring the fearful, stimulating the exhausted, debating with managers and always going further to full agro-devotees' are all actions to implement to put them on the way toward diversification.

This analysis is a starting point for the development of a typology that has to be further investigated. As it was not the first focus of the study the list of priority management is not exhaustive and other interviews would highlight other categories. However, this categorization of farmers can help better designing information given by consultant so that they reach the receiver. While information emerging from the two different categorizations is complementary, the primary factor needs to be the first focus of investigation to allow an understanding of the global brakes before going to information focused on crop diversification.

3.4. Focus on low input crops

3.4.1. Experiences and curiosity

In this first part I drew a classification of low input crops based on curiosity and experience of farmers toward those crops (see figure 5). Some crops were more often quoted spontaneously according both to farmers' experience and curiosity. If I precise "spontaneously" it is to make a difference with crops quoted after showing the list.

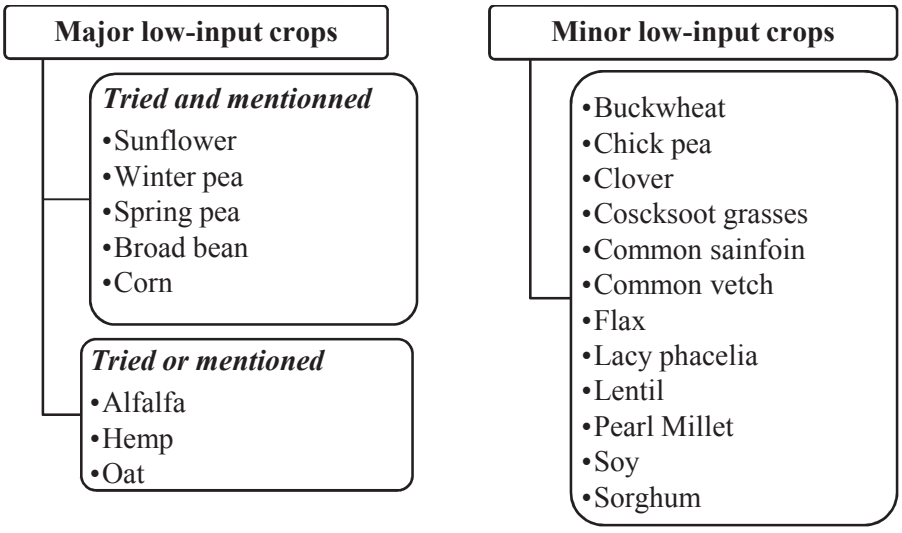


Figure 5- Low input crop classification according to farmers' experience and curiosity

Major low-input crops

The majority of farmers interviewed had already crop sunflower (see appendix 11). For comparison, farmers have as much experience about spring barley (retained as intermediate crop, see 2.3.1.1.) as they have about sunflower. In general, farmer also tried four other crops: winter and spring peas, broad bean and corn. The percentage of farmers who quoted those crops being greater than percentage of trials, many inexpert farmers have insights about it.

In general, crops that had already been cultivated by at least half of farmers interviewed were the one that were more often quoted spontaneously. However, while less than half of farmers had already crop alfalfa and hemp, around half of them quoted this crop spontaneously. Oat has an intermediate position but farmers have more experience about oat than about both hemp and other minor crops.

Minor low-input crops

When the list was showed to the farmer they emphasized on crop that they had already quoted and they quoted crops that they did not quote before. For the second type of crops, more often it was common sainfoin, sorghum, oats and alfalfa (30 to 40% of farmers) followed by soy, flax and cocksfoot grass (20 to 30% of farmers).

Alfalfa is both part of spontaneously quoted crops and crops quoted after reading the list but less than a half of the farmers had already crop it. This information suggests that if a marketing solution was given for alfalfa, it would be easy to convince farmers to crop it.

3.4.2. Beliefs and knowledge

In this part, I will present positive and negative opinions *that farmers expressed* on selected crops and give suggestions for local institution to limit the impact of negative opinions. In a first time, when data allowed us, crops were treated one by one in coherence with the classification drawn in the previous section then, general conclusions were drawn.

Major low-input crops

Most of the farmers pointed out the low amount of input required to cultivate **sunflower** whether or not they had experience with this crop. By contrast, the need for specific equipment is the dominant brake highlighted by experienced and inexpert[6] farmers. Experiences farmers also complained about birds which feed on seeds and greatly impact the margin (see appendix 12, table 1). Farmers also stated that margin and yields are impacted by other factors such as soil conditions or

[6] In this part, exeperienced farmer refer to farmer who already cutlivated the crop while inexpert refer to farmer who had never cultivate the crop.

varieties available. Data from Vegellia confirms this decline in yields: 34.3 t ha^{-1} in 2011, 28.5 t ha^{-1} in 2012 and 22 t ha^{-1} in 2013. Acknowledging the market potential, it could be interesting to investigate on the causes of this decline to determine adapted solutions. Finally, concerning the working period farmers have different perceptions. Trying to link farmers' priority management with either positive or negative opinion on working period did not highlight any trend. For example, two winegrowers expressed opposed opinions while grape picking can overlap with sunflower harvest.

According to farmers**, spring and winter peas** are difficult to harvest because of the amount of stone on soil surface and they are not suited to local climate conditions. In addition, in the 1990's, many farmers of the territory observed disastrous yields because of *Aphanomyces euteiches* a pathogen that lives in the soil and provokes roots rot. Since this time, most of them are reluctant to reintroduce pea in their cropping system. Concerning positive aspects, the majority of experienced farmers agreed on the positive rotational effect (Schneider et al, 2010). However, inexpert hardly perceived it. Climate and soil being unchangeable it is challenging to find arguments to introduce the current varieties of pea within current market situation. However, varieties that present a better standing ability would be welcomed by the farmers. Concerning *Aphanomyces euteiches* advisors could introduce to farmers the affordable tests that exist.

Concerning the ability of the stem to stand, according to farmers, **broad bean** has the reputation to be easier to harvest than pea. They also acknowledge it positive rotational effect. However, broad bean was pointed out for multiple negative aspects. Farmers have doubts about the yield potential and thus the gross margin that they could obtain from this crop under local soil and climate condition. They also questioned market opportunities for this crop. Finally, it disappearance of absence on the territory did not reinsure them. Regarding market opportunity, market for human consumption should be targeted if the farmer is not breeder. However, *Bruchus pisorum* attacks being the limiting factor it could be interesting to investigate on territorial actions that could be taken to limit the problem.

The first advantage associated to **corn** is it adaptation capacity to specific soil conditions that are not suitable to other crops. This crop is traditionally implanted in specific "valley" soils but some famers (e.g. farmer 5) are currently experimenting corn on any type of soil. This type of initiative should be followed by an advisor and showed to other farmers. Experienced farmers also highlighted the advantage at the cropping system scale in terms of weeding. By contrast, the need for specific equipment, the low margin associated to low price and game issues are negative aspects addressed. Finally, inexpert farmers worried about the disappearance of corn from their territories. Indeed, it declined from 729 to 420ha between 2012 and 2013 and yields are declining since 2011.

All farmers have convergent opinions on **alfalfa**: it has a positive rotational effect but few or even no market opportunity. Those conclusions led farmer to consider cropping alfalfa without selling it but simply taking advantage of it positive impact on soil, pests, diseases and weeds. However, low yields and logistical complications are criticized. Local institutional actors should work together with collect actor to build a strategy that could ensure alfalfa collect on the territory without being too restrictive for collect actors.

While only two farmers had already cropped it, **hemp** received the widest range of negative comments. Need for new equipment, need for contract and the working period are the most important brakes highlighted by farmers. Farmers feared to injure their harvesters; they feared the need for both stocking areas and specific material. Those points were highlighted by experienced and inexpert. Some divergent points of view emerged dealing with agronomical impact. It could be a positive initiative to inform farmers on impact at the rotational scale and on the soil.

Oats also received many negative comments but was not quoted spontaneously as often as other major low-input crops. There is an important lack of knowledge on this crop. First of all, most of the farmers depicted oats as an old fashion crop, "*the crop of my grandfather*" which impacts its development potential. Moreover, while experienced farmer did not quote it, inexperts stressed the harvest and climate issues. The marketing opportunity issue which was pointed out by farmers was also stressed by storage agencies. Finally, experienced farmer insisted on the low input character of oat and its interests at the rotational scale.

Minor low-input crops

For some minor crop, I did not collect enough data to draw detailed conclusions. However, for some of those crops (sorghum bicolor, soy, lentil, chick pea and pearl millet) I observed concordant conclusions:

- Experienced and inexpert agreed on a non-suitable climate for **sorghum** crop.
- Two farmers observed that **soy** disappeared from the territory and link it to unsuitable climate conditions. Moreover, farmer 5 considered implanting soy but did not because the information he got is that it needs more rain and more heat than local climate can offer.
- Inexpert farmers raised concern on **lentil** harvest issues linked to soil conditions (stones)
- One farmer that experienced **chick pea** described it as a crop which stem has a great standing ability.
- The same farmer pointed out the positive rotational effect of **pearl millet**.
- Two inexpert farmers per each have fear regarding to **buckwheat** and **common sainfoin**

Concerning the others, for different reasons I could not bring out any convergent opinion:

- Three farmers that had already cropped **clover** expressed opinion about it but no agreement was observed.
- **Flax, cocksfoot grasses and common vetches** were cropped by one farmer each but none of them expressed opinion on those crops
- None of the farmers interviewed tried **common sainfoin** or lacy **phacelia**.

In general, inexpert farmers consider that implanting a cover crop they "*throw money by the window*". This feeling hinder introduction of any spring crop as implanting a cover crop is mandatory if the soil is bare during rainy periods (Environment code, Article R211-81, 2011). Furthermore, it emphasis on a more important issue which is their poor system approach capacity: in general inexpert farmer do not recognize advantages of crop at the rotational scale.

Acknowledging experiences, curiosity and opinions on low-input crops, local consultants could differentiate real knowledge from groundless beliefs and better target information given to farmers. Working on ways to solution negative aspects and bringing to light beliefs could enhance farmers' engagement toward crops diversification.

3.5. Improving water quality with local institutions and farmers

3.5.1. One goal, multiple solutions

Diversification can occur in a variety of ways (Lin, 2011). In this paper we chose to focus on increasing rotational diversity at the landscape scale. This situation can be reached by multiple actions and interactions of local stakeholders. Some of them are drawn in this section but much different processes could be considered in order to increase farmers' involvement toward crop diversification (Ravier et al, 2015)

Spot diversification

The principle is that different groups of farmers introduce a crop that present market issues (see figure 3). Few or any local references on technical management are available for most of those crops. Moreover, marketing those crops can require working with different actors than they currently do. To minimize those issues, local institutions have the responsibility to provide farmers with knowledge on market and technical advices. In a first time, they can gather that information by seeking for farmers who have experience with those crops. It is a good starting point for the project because it will initiate a group dynamic among farmers and between farmers and local institutions. Second step would be to gather knowledge from external sources, either by inviting external experts or by

reviewing technical literature. Eventually, experimental plots can be designed to assess potential of different varieties or different technical managements under local soil and climate conditions. Finally, both farmers and consultants should keep open ears to information about new crops or new market opportunities. In this frame, having a consultant working on niche market opportunity could be a useful initiative. In the chamber of agriculture there is a service of marketing solution dedicated to major crop. The market for this kind of software/ tool is wide and competitive. However, it could help both farmer and chamber of agriculture to create a service for advices on niche market. The person in charge of this unit would have the responsibility to inform himself about any niche market that exists at a local or national scale. For this type of diversification, it seems that agro-devoted, exhausted, agro-intensive, breeders or trader could be willing to get involved. However, it will not suit to each of the other type of farmers, for example fearful farmers could be reluctant. Finally because of market opportunities and other inherent factors, it cannot represent important surfaces.

Focused diversification

Focused diversification without market improvement consists in enhancing introduction of marketable crops through price support. Corn, lentils, peas, soy and sunflower are marketable crops that were criticized for reasons often including low margin caused by low yield under soil and climate conditions. However, most of the farmers attributed positive aspects such as low-input demand for sunflower and positive rotational effect for pea. Thus, by compensating the negative aspects, price support could convince hesitating farmers. The price support should be considered as compensation in case of low yields or low prices. Apart for soy, there are local references for each of those crops. From those references, the mean management charge should be calculated. Moreover, because farmers often expect a margin that equals rapeseed's margin, it would be used as a benchmark for calculation. Thus, farmer could be compensated up to rapeseed's observed margin acknowledging management cost, mean yields and mean price. Advantage of this method is the wide range of farmer that would be interested. Indeed, fearful and pre-retired could prefer this solution to more risky diversification (spot, association-based or system). By contrast, a limit of this method is it sustainability and it cost for the institution that settle it. Moreover, it does not involve farmer in a common approach and thus does not stimulate interactions among peers.

Focused diversification with market improvement consists in the creation or development of a sector for a crop. In this situation, further market investigations should be carried on about the potential national and international market. Indeed, if there is no wide market, sector cannot be sustainable. Doing research on market opportunities, there is still some insight about different crops. Common vetch and oilseed flax are one of those.

Agronomic diversification

System diversification does not require market improvement, however it is knowledge intensive and it impacts are not proven. What is meant by system diversification is the introduction of new crops via different cropping systems. Cover crops and crop associations are two examples that will be described because farmers talked about it during the interviews.

Different types of cover crops can be considered in this system. First it can be a crop that will be destructed before harvesting the main crop. This technique already exists on the territory. Another option is the perennial cover crop. For example, alfalfa, clover or common sainfoin could be used. Concerning the impact, while most agree on decreased need for fertilization, it can increase pesticides use. Indeed, if the non-perennial crop has to be destructed chemically, it increases herbicide use. In this situation, alternative is either to use a crop that easily freeze (common vetch for example) or to destruct it mechanically. Moreover, if there is a need to slow down perennial cover's growth, it can increase chemicals use. Improvement of this technique would be to bring cattle to graze between two crops. These methods rely on agronomy and thus are knowledge intensive thus each type of farmers will not be willing to do implement such system which seems to be more adapted to agro-devoted or agro-intensive farmers. For example, the two farmers that quoted this system were agro-intensive. Finally to enhance the adoption of such system local institutions would need to provide knowledge on the best management practices. Moreover by giving subsidies for farmers to buy seeds and seed they could increase adoption of such techniques.

Crops' association-based diversification with or without market improvement consists in associating a major crop with a low input crops. Many research have already been carried out on associations between cereal crops and leguminous. In the current situation associating either barley of wheat with pea, lentils or broad bean could increase crop diversity without major change for farmers. In this situation the role of local institution is either to work together with marketing actor for them to better accept crop mix or subsidize acquisition of crops' sorter that farmers could share.

3.5.2. Need for a shared goal

This research could be considered as the first step of an action research process. By interviewing farmers and assessing market opportunities for low input crops, I got a broad overview of the current situation. Presentation of findings to respondents and local institutions could initiate a reflection about project that they could initiate all together to improve water quality. Indeed, keeping those results in the institutional frame without sharing with farmers would not be as efficient as a cycle of action research (Barbier et al, 2010). Such a participatory approach would answer farmers' need for building a common future and build a "*rural social capital*" (Bacon et al, 2012).

Thanks to collectivization of marketing through emergence of cooperatives they worked together to answer need for new marketing strategies induced by globalization. Then, with creation of GDA, most of them started to work with the objective of lowering input use while keeping yields at the same stage. Currently, while different groups are working on specific topics those are punctual initiatives and groups are often composed by the same farmers. This lake of links between groups limits the emergence of new ideas (Burt, 2004). Moreover, many of them see the others as competitor instead of considering them as partners. Their willingness to have the highest yield, the lower quantity of weed in their fields is often tangible. Anything which reinforces this competition has negative impact on their ability to work together. Local institutions should encourage farmers to solve their problem together instead of showing their strengths and hide their weaknesses. The role of local institution would be here to lead farmers to ask themselves the good questions and answer it together (Lemery, 2003).

As an example, risk assessment programs could lead farmers together with local institution to reflect on shared issues. Pricing or miss-pricing of risk is one of the factors influencing adoption of new practices. Thus, anything which could help farmers having a complete understanding of risks associated to change would favor those changes. A risk assessment programs could consist in workshops where farmers together with expert draw different situations on long term and short term. In each situation the risk is assessed and a comparison of each situation highlights the most risky ones. This could increase interactions and avoid overestimation of the risk associated with crop diversification.

4. Conclusion

As a pre-requisite I selected and classified low-input crops according to their market potential. While the list is consistent, market investigations were not deep enough and collect actors were not transparent enough to give sufficient information to draw definitive conclusions. However, a classification of crop according to the market special features gave an interesting overview.

Semi-directive interviews with farmers allowed understanding their behavior and attitude toward crop diversification. Stating that farmers of the territory studied are or are not ready to increase the diversity of crops that they cultivate would be an easy but incomplete way of closing the debate. By contrast carrying this research project I brought to light the complex components of their behavior. Attitude toward their peers and farmers' favorite aspect of farming were highlighted as being the most important factors to understand. Further than being manager, trader, agronomist and any other profession at the same time they are social beings. What I highlighted is that interactions oriented toward common goal would put any farmer from any of the category drawn in this paper in a better

position for changing. Moreover, by understanding dominant personality trait or farmers' favorite aspect of farming, consultant could adapt orientation of information in order to reach farmers.

Farmer's current situation is critical because they rely on few crops and few buyers. It appears as a vicious circle: their vulnerability increases their aversion to risk; their aversion to risk hinders changes and the longer they remain in this situation the more vulnerable they get. However they are conscious of the situation: many of them both stressed the need for change and a lack of willingness to change. This contradiction is better explained by their vulnerability and lack of self-sufficiency than by structural or technical characteristics. Whether or not local collect and stock actors are willing to change, possibilities to introduce crop and even low input crop on the territory exist. However, those changes would require material or economic investments from local institutions. Any of these results has to be relativized acknowledging the frame of the research. Field work was carried on by nonprofessional on restricted territory with a restricted number of farmers.

This kind of program by fitting with Water Framework Directive could receive the needed investments if it is well designed. This project led me to shape solutions that require more work to be operational. Thus, I stress the need for investigations on the feasibility, the stakeholders and institutions to enroll in such ways toward diversification. While this research was carried on without involvement of market actors, local institutions should work together with them about valorization of selected crops. Finally substantial work on finding ways to involve more farmers on designing their own strategy of improvements together with local institution would be a win-win solution for agricultural stakeholders. The results drawn in this paper show the importance of understanding the multiple facets of farmers' behavior to guide them on the way to change.

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Table of appendixes

Appendix 1 - Datat from agricultural census (Source : Recensement agricole, Agreste, 2010)

		Exploitations agricoles ayant leur siège dans le département		
Libellé du département	**Région**	**2010**	**2000**	**1988**
Aube	Champagne-Ardenne	5 243	5802	7714

Travail dans les exploitations agricoles *en unité de travail annuel*			**Superficie agricole utilisée** *en hectare*			**Cheptel** *en unité de gros bétail, tous aliments*		
2010	**2000**	**1988**	**2010**	**2000**	**1988**	**2010**	**2000**	**1988**
8 871	9241	10895	374 639	380917	375429	74 737	83449	89962

Superficie en terres labourables *en hectare*			**Superficie en cultures permanentes** *en hectare*			**Superficie toujours en herbe** *en hectare*		
2010	**2000**	**1988**	**2010**	**2000**	**1988**	**2010**	**2000**	**1988**
345 492	349698	337074	7 436	6526	5604	21 246	24384	32077

Appendix 2 - Score of crop rotation diversity

Method (Source : Agreste, 2010):

Crops' group :

Wheat – Barley - Corn (grain or forrage) – Oat – Triticale – Rye - Sorghum (grain) - Rice or other cereals' mix - Beetroot for industry use – Rapeseed- Sunflower – Soy - Hops, tobacco, PAPAM, seeds production, chicory, endive roots, other industrial crops - peas * - faba bean * - Lupin, linseed, other oilseeds, pulses, fiber crops - Fodder roots - Forage legumes and other forages - Potatoes - Fresh vegetables, melons and strawberries - Flowers and ornamental plants – Vineyards - Orchards certain table apple fruit table pear, peach, cherry, plum, apricot - other orchards – fallows

Calculation method:

The score of the farm is initialized at 10. It decreases from tenth of the surface of a group of crops that exceeds 10% of the UAA. If a group occupies 100% of the UAA of farm, the farm will score 1 point (10 minus 9 points)

If a group occupies 30% (3/10) of the UAA of operations, the score is 8 points (10-2).

The score of an area (county or municipality) is obtained by average scores of farms, weighted UAS farm in the canton.

The data are located in the headquarters of the farm. When the area has 1 or 2 farms it holds the score of the department.

The scores from 2010 agricultural census were calculated on all farms, including farms managing grazing land, excluding vacant farms. The scores calculated from agricultural census in 1970 do not include the 4 groups marked with *.

Farms and surfaces are located at the farm headquarters.

Scores of cities that have 1 or 2 farms were replaced by the average scores of the department.

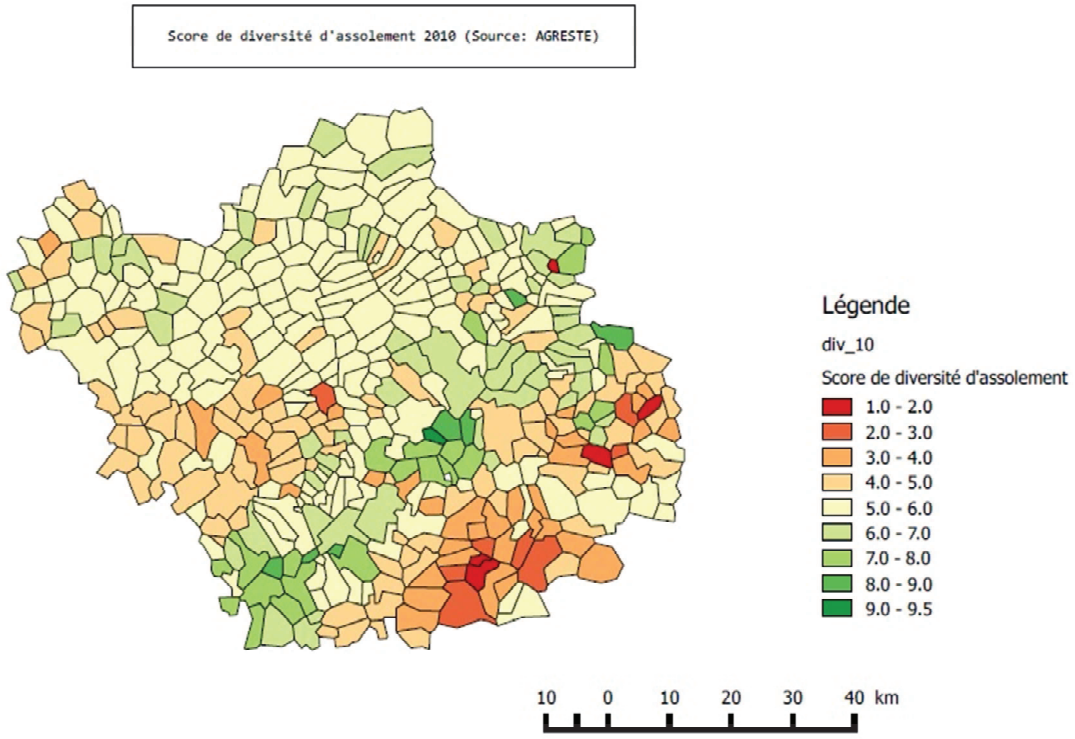


Figure 1 - Map of score of crop rotation diversity (Source: data from Agreste, 2010; Map: Vereecke L., 2015)

Appendix 3 - Departmental hydrology and pollution of groundwater bodies

In terms of hydrology, there are four watershed areas and two main rivers: the Seine and the Aube. Three secondary rivers are observed, the Vanne, the Armançon and the Armance rivers. However, no alarming pollutants were found in surface water in the department. Concerning groundwater, it ensures the totality of water used for human purposes. Those water bodies are managed together with all water bodies of the "Seine Normandie" river basin. Under the frame of the water framework directive, a river basin management plan was written in 2000 with goals to meet in 2014. At the end of the plan water quality was assessed. As a result, only two of the thirteen groundwater bodies present in the department were in a good chemical status. Indeed, in 2013 pesticides were found in each groundwater body and nitrates were found in one. Concerning nitrate pollution, it is found in the form of NO3 and the water agency statefd in 2013 that, agriculture is the main responsible when this molecule is found. Coming to pesticides, four different molecules occurring from agriculture are often found in groundwater bodied. Two of them are currently forbidden (atrazine and desethyl-terbumeton) and the two others that are still allowed (glyphosate and bentazone).

Regarding to drinking water catchments of the territory, in the Pays d'Othe area, fifteen were identified as facing a pollution issue either linked to nitrate, to pesticides or both (Comité de basin agence de l'eau Seine Normandie, 2013). Moreover, one of those drinking water catchments was and is still considered as "Grenelle" by the French government which means that it is part of the most vulnerable and strategical catchments. In Barrois area, eighteen drinking water catchments faced an excessive amount of pollutants and six are classified as Grenelle (Roussary A. et al, 2012). Finally, in the territory, the pollutants found are mostly agrochemicals and nitrates. Assuming that around seventy percent of nitrate pollution in water occurs from agriculture (Turpin N. et al, 1997quoted in Cemagref- CACG, 1997) and agrochemical pollution occurring from community use is negligible in rural areas, we can state that water pollution in the department is strongly influenced by agricultural practices.

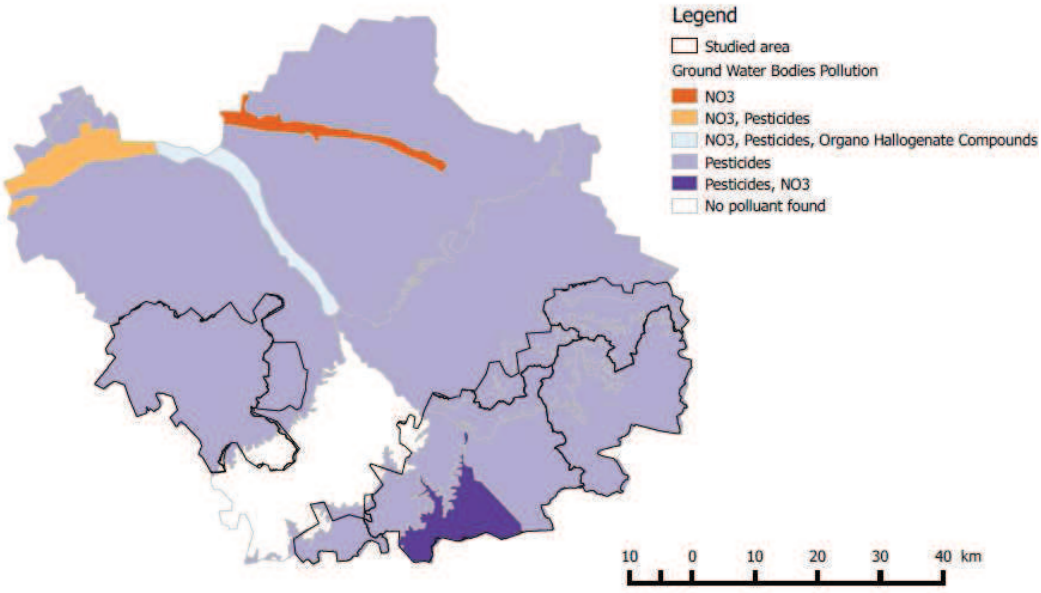


Figure 2 - Pollutant found in ground water bodies situated in the French department of Aube (Source: data from Agence de l'eau Seine Normandie, 2014 - Map: Vereecke L., 2015)

Appendix 4 - Data from Vegellia (Sources: Vegellia, 2012; Vegellia 2013)

	2011			2012		
	Barrois	Pays d'Othe	**Total**	Barrois	Pays d'Othe	**Total**
Blé tendre d'hiver	2615,22	991	**3606,22**	2623,88	1745,43	**4369,31**
Colza hiver	2055,77	648,45	**2704,22**	2393,56	1265,6	**3659,16**
Orge d'hiver	1552,48	395,3	**1947,78**	752,48	903,11	**1655,59**
Orge de printemps	393,22	288,06	**681,28**	812,41	505,62	**1318,03**
Tournesol	83,89	57,3	**141,19**	131,73	98,29	**230,02**
Pois hiver	176,09	79,44	**255,53**			**0**
Maïs	92,77	53,78	**146,55**	142,33	7,6	**149,93**
Pois printemps	32,4	47,35	**79,75**	88,48	54,13	**142,61**
Chanvre fibres					69,71	**69,71**
Lentille				3,03	28,5	**31,53**
Betterave						

	2013			**Moyenne 2011 - 2013**	**Moyenne 2011 - 2013 %**
	Barrois	Pays d'Othe	**Total**		
Blé tendre d'hiver	3440,4	1825,2	**5265,6**	**4414**	**38%**
Colza hiver	2385,7	1225,6	**3611,3**	**3325**	**29%**
Orge d'hiver	2120,9	968,1	**3089,0**	**2231**	**19%**
Orge de printemps	649,6	320,9	**970,6**	**990**	**8%**
Tournesol	179,3	97,6	**277,0**	**216**	**2%**
Pois hiver	204,9	18,3	**223,2**	**160**	**1%**
Maïs	79,1	30,9	**110,0**	**135**	**1%**
Pois printemps	93,4	33,0	**126,3**	**116**	**1%**
					0%
Chanvre fibres		97,3	**97,3**	**56**	**0%**
Lentille	7,3	21,8	**29,1**	**20**	**0%**
Betterave	9,6		**9,6**	**3**	**0%**

Appendix 5 - Selection of low input crops

Table 1 - First list of crops that were thought to be low-input demanding

Leguminous	*Rustic cereals*	*Crops known as being low input*	*Seed crops*
Alfalfa	Common sainfoin	Buckwheat	Cocksfoot grasses
Spring and winter broad bean	Petit épeautre	Fiber and oilseed flax	Lacy phacelia
Clover	Epeautre	Hemp	
Spring and winter lentil	Seigle	Corn	
Chick pea	Triticale	Soy	
Spring and winter protein pea	Pearl Millet	Sunflower	
Common vetch	Spring and winter oak		
	Surghum bicolor		

Table 2 – Data collection, treatment frequency

		other	BC	BN	BS	PO	mean	
Crop	*Latin name*	IFT crop is … to IFT criterion						Nb data
Alfalfa	*Medicago sativa*	<	<	<	<	<	<	*5*
Buckwheat	*Fagopyrum esculentum*	<	<				<	*2*
Common sainfoin	*Onobrychis viciifolia*	<		<			<	*2*
Corn*	*Zea mays*	<					<	*1*
Hemp*	*Canabis sativa*	<	<	<	<	<	<	*5*
Lacy phacelia	*Phacelia tanacetifolia*		<			<	<	*2*
Pearl millet	*Pennisetum glaucum*	<	<				<	*2*
Soja	*Glycine max*	<			<	<	<	*3*
Sorghum	*Sorghum bicolot*	<		<			<	*2*
Spring oak	*Avena sativa*	<		<	<	<	<	*4*
Sunflower*	*Helianthus annuus*	<	<	<	<	<	<	*5*
Spring oilseed flax	*Linus usitatissimum*		<=	<		>	<=	*3*
Cocksfoot grass	*Dactylis*	>	>=		<=	<	=	*4*
Winter pea*	*Pisum sativum*	=		>=	>	<	=	*4*
Chickpea	*Cicer arietinum*	>=		<	>		>=	*3*
Clover	*Trifolium*	>				>=	>=	*2*
Winter oak	*Avena sativa*	>	>=	>	<	>=	>=	*5*
Common vetch	*Vicia sativa*	>=			>	>	>	*3*
Einkorn wheat	*Triticum monococcum*			>	>		>	*2*
Fiber flax	*Linus usitatissimum*	>					>	*1*
Lentils	*Lens culinaris*	>	>		>	>	>	*4*
Rye	*Secale cereale*			>	>	>=	>	*3*
Spelt	*Triticum spelta*	>	>	>	>		>	*4*
Spring broad bean	*Vicia faba*	>	>	=		>	>	*4*
Spring pea*	*Pisum sativum*	>			>	>	>	*3*
Triticale	× *Triticosecale*			>	>	>	>	*3*
Winter broad bean	*Vicia faba*	>	>			>	>	*3*
Winter oilseed flax	*Linus usitatissimum*	>		>			>	*2*
Lupin	*Lunpinus*							*0*
Quinoa	*Chenopodium quinoa*							*0*

Table 3 – Data collection, N fertilizer

		other	BC	BN	BS	PO	mean	
Crop	***Latin name***	**uN crop is … to uN criterion**						**Nb data**
Alfalfa	*Medicago sativa*	<	<	<	<	<	<	5
Buckwheat	*Fagopyrum esculentum*	<	<				<	2
Chickpea	*Cicer arietinum*	<	<	<	<		<	4
Clover	*Trifolium*	<		<		<	<	3
Common sainfoin	*Onobrychis viciifolia*	<	<	<			<	3
Common vetch	*Vicia sativa*	<		<			<	2
Fiber flax	*Linus usitatissimum*	<					<	1
Lentils	*Lens culinaris*	<	<		<	<	<	4
Pearl millet	*Pennisetum glaucum*	<	<				<	2
Lacy phacelia	*Phacelia tanacetifolia*		<				<	1
Soja	*Glycine max*	<			<	<	<	3
Sorghum	*Sorghum bicolor*	<					<	1
Spring broad bean	*Vicia faba*	<	<	<	<	<	<	5
Spring oak	*Avena sativa*	<	<	<	<	<	<	5
Spring oilseed flax	*Linus usitatissimum*		<	<		<	<	3
Spring pea*	*Pisum sativum*	<			<	<	<	3
Sunflower*	*Helianthus annuus*	<	<		<	<	<	4
Winter broad bean	*Vicia faba*	<	<			<	<	3
Winter oak	*Avena sativa*	<	<	>=	<	<	<	5
Winter oilseed flax	*Linus usitatissimum*	<		<			<	2
Winter pea*	*Pisum sativum*	<			<	<	<	3
Cocksfoot grass	*Dactylis*	<	=		<	>	<=	4
Hemp	*Canabis sativa*	=	<	>	<	>	=	5
Corn*	*Zea mays*	>					>	1
Einkorn wheat	*Triticum monococcum*			>	>		>	2
Rye	*Secale cereale*	>			>	>	>	3
Spelt	*Triticum spelta*	>	>	>	>		>	4
Triticale	*× Triticosecale*			>	>	>	>	3
Quinoa	*Chenopodium quinoa*							0
Lupin	*Lunpinus*							0

Table 4 – Crop that were not kept for further investigations

***Reliability*: 1 = no divergent data and at least two data per criterion; 1.1 = no divergent data but only one data for at least one of the criterions; 2 = divergent data for one criterion and at least two data per criterion; 2.2 = divergent data for one criterion but only one data for at least one of the criterions; * = local (territory or department scale) data from Vegellia**
***TIF*: (<) = crop requires less treatments than spring barley; (<=) = crop requires less or as much treatments as spring barley; (>) = crop requires more treatments than spring barley; (>=) = crop requires more or as much treatments as spring barley; (?) = no information**
***Data*: total number of answers for this criterion**
***N fertilizer*: (<) = crop requires less N fertilizer than spring barley; (<=) = crop requires less or as much N fertilizer as spring barley; (>) = crop requires more N fertilizer than spring barley; (?) no information)**

Crop	***Latin name***	**TIF**	**Data**	**N fertilizer**	**Data**
Spelt	*Triticum spelta*	>	4	>	4
Einkorn wheat	*Triticum monococcum*	>	2	>	2
Rye	*Secale cereale*	>	3	>	3
Triticale	*x Triticum spelta*	>	3	>	3
Lupin	*Lupinus*	?	0	?	0
Quinoa	*Chenopodium quinoa*	?	0	?	0

Appendix 6 - Classification of low-input crops according to their market potential

Table 1 - Marketable crops

	In general	On the territory
Corn (*Zea mays*)	Market does not seem to be a limiting factor	Most of actors interviewed buy it.
Lentil (*Lens culinaris*)	Market does not seem to be a limiting factor. Quality standards: Main use is food thus grain should not be affected by blight; it should not germinate and not be broken. Moreover, when harvesting specific attention should be given to stones which can be mixed with lentils.	The two main actors buy it through contract with a specific price settled at sowing. There is a need for stocking on farm and farmer has to assure 15-20ha min surface for logistical issue (30T trucks).
Peas (*Pisum sativum*)	Market does not seem to be a limiting factor. Price fluctuates and is indexed on wheat's price. - *Green pea (fresh, frozen, canned)* Quality standard: the intensity of the green color for green peas; the percentage of broken grains for dry peas. Price : 200 – 220€/T - *Field/Dry pea* *Animal feed*, there is a European market. In feed processing industry, row material is substitutable and they can have more soya than peas which does not favor the use of protein pea for feed production. It has strong impact on prices. *Human consumption*, there is an international market for split pea. It could be interesting to get more information about this market. Quality standard: percentage of broken grains Price : 180-200€/T	Most of actors interviewed buy it. The processors are situated in Britany on in the North department which induces high logistical expenses.

	- *Starch and protein extraction* The use of pea for starch production seems to be a developing market. This vegetal protein meets the need for a decrease in animal protein use.	
Soja (*Glycine max*)	Market does not seem to be a limiting factor. However, price is because of South America which is a strong competitor. They produce high quantity for low price.	Some actors buy it. One actor has the objective to increase quantity by developing an integrated market.
Sunflower (*Helianthus annuus*)	Market does not seem to be a limiting factor. The varieties cropped are oilseeds sunflower processed in crushing units.	Most of actors interviewed buy it.

Table 2 – Opportunity minor crops

Broad bean (*Vicia faba*)	Market is narrow. - *Feed* The national production is considered as being too narrow for feed processors. Quantity facilitates commercialization. Thus it would be more recommended in regions where there is cattle production which can price the production. Price : 200 – 220€/T - *Food* Export market for Egypt and some Asian countries. Narrow but constant. Quality standard: main problem is *Bruchus pisorum* attack the tolerance is low and few applications of insecticides are allowed. Thus quality standard are hardly met. Price: 280-300€/T	Most of actors interviewed buy it.

Buckwheat (*Fagopyrum esculentum*)	Market is narrow and easily filled. Main use is production of specific flour used in Britany to bake crepes. There is a narrow market for bird-breeding as well. It might be a developing market for gluten free products (bread or direct consumption). When the climate is suitable for farmers to seed a second main crop they often seed buckwheat and thus fill the market.	Most of actors interviewed buy it (but all complain about the market opportunities)
Oak (*Avena sativa*)	Market is narrow and fluctuates. It is a European market for horse feed. If the production increase one year, it becomes impossible to market the product. To investigate: It might be a demand from horse riding professionals to buy special packaging of 20kg bags	Most of actors interviewed buy it.
Pearl millet (*Pennisetum glaucum*)	Market is narrow and fluctuates. It might develop because main producers in Eastern Europe stop it production. Quality standards: if used for bread making grains has to present a certain intensity of yellow and less than 2% of impurity might be found. If it is a bit too grey, it is used for bird-breeding and if it is even greyer it goes for cattle feed. Yield: 10-50qx Price: 200-230€/T	Main actors already bought it but they are not willing to continue because it is hard to market it.
Sorghum (*Sorghum bicolor*)	Market is narrow. Used for cattle feed and bird-breeding.	None of the actors contacted buy it.

Table 3 - Contract minor crop

Nacked oak (*Avena nuda*)	Integrated market which needs regular quantities. Used for human consumption. Quality standard: use of stocking insecticide is forbidden, no more than 2% of the grains can present husk. Price: 250€/T	Only one buyer was identified. The actor has a small development capacity for this production. Logistic requirements: It has to be delivered to the silo or they can provide "trucks in field" when the plot is not further than 30km from the silo.
Chick pea (*Cicer arietinum*)	Integrated narrow market which is fluctuating. Important concurrence from import (Canada and Russia mainly). This concurrence induces a fluctuation of prices. Price : 500 – 600€/T	Only one buyer was identified. The actor does not have a capacity of development for this production.

Table 4 - Specialist's crop

Flax *(Linum usitatissimum)*	- *Oilseed flax* Market seems to be developing for cattle feed with the interest of reintroduction of omega 3 and 6. Belgium is the biggest actor in the market because they have the biggest crashing units. Market for direct human consumption seems to be developing as well.	None of the actor of the territory buys oilseed flax. This is an integrated market owned by few actors situated in the North and North West of France. - *Fiber flax* A specific need for seed multiplication contracts was identified but it is not low input demanding.
Hemp (*Canabis sativa*)	No data	The totality of the local production is managed by one actor which does not seem to have development capacity at this time.
Alfalfa	- *Dehydrated forage*	Local dehydration units do not seem to

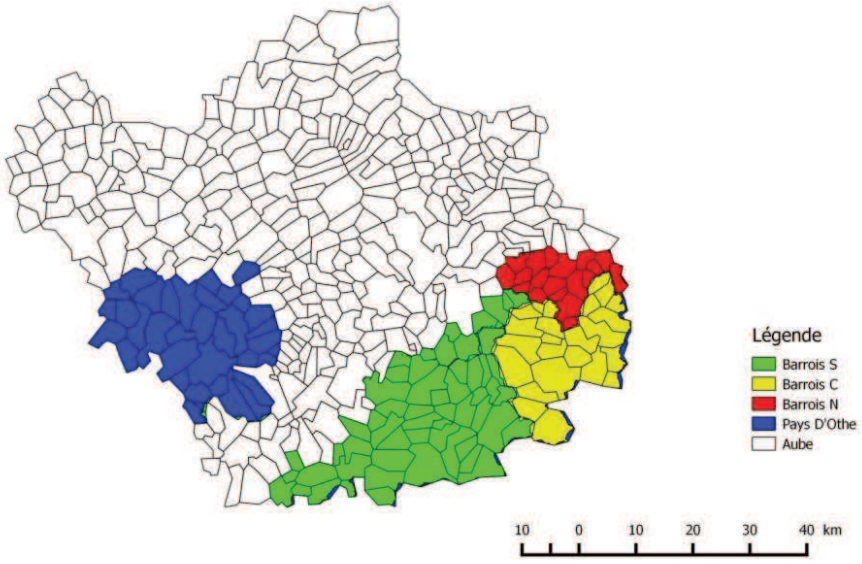
(*Medicago sativa*)	No data on global market. Dehydration units require important quantities of material to be profitable. The price of the pellet is highly versatile and controlled by a unique actor. - *Forage* - *Seed multiplication*	have any development capacity. As read in the local newspapers, actors from this sector tend to predict an increased need for alfalfa forage. The territory is too far from the units to be collected, it is not economically interesting for those existing units. Different seed suppliers expressed needs for geographical diversification of their production. One of the subterritories, Pays d'Othe, could meet their expectations in term of localization and soil and climate conditions. However, for technical reasons plots have to be as clean as possible.
Common sainfoin *Onobrychis viciifolia*	No data on global market	Totality of forage production is managed by one actor which does not seem to have development capacity. Another actor was identified for seed production.

Table 5 – Cover and grassland crops

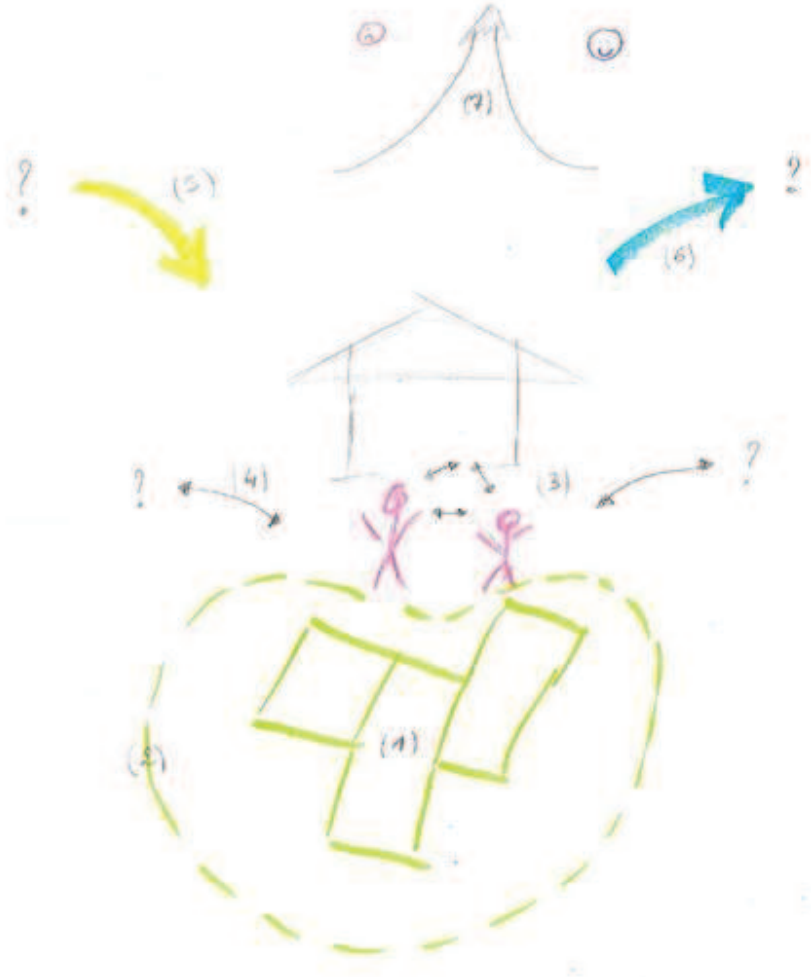
Clover (*Trifolium*)	Market is narrow and fluctuates. National market is easily saturated thus the European demand determines the market.	Some of the actors interviewed buy it.
Cocksfoot grasses (*Dactylis*)	Market is narrow.	Some seed suppliers interviewed buy it.
Common vetch (*Vicia sativa*)	Market is narrow and changes. National market is dedicated to cover crops and there is a risk of decrease because, the advantage of vetch is that it freeze easily but lasts winter, temperature were not low enough.	Some of the actors interviewed buy it.

	To be investigated: There is a market for cattle feed and bird-breeding in Northern Europe.	
Lacy phacelia (*Phacelia tanacetifolia*)	Market is narrow.	Some seed suppliers interviewed buy it.

Appendix 7 - Division of the territory for the geographical localization criterion (Source Vereecke L., 2015)



Appendix 8 - Scheme showed to the farmer during the first part of the interview



Appendix 9 - Definition of codes used for interviews analysis

"Div."

B0: The farmer is not diversified at all, he is cropping winter wheat, winter barley and canola. It can happens, if the climate force him, that he sow spring barley.

B1: the farmer is mainly cropping winter wheat, winter barley and canola. Irregularly, for non-climatic reasons, he sows another crop which can be spring barley or any other crop.

B2: the farmer is mainly cropping winter wheat, winter barley and canola. Last year, this year or next year he sown or he is planning to sow protein pea or sunflower. The objective is a perennial introduction of this crop in the crop rotation.

B3: the farmer can be mainly cropping winter wheat, winter barley and canola or not. Each year, for two or more seasons, he has another crop which is not spring barley.

Concerning the "**agricultural information network**", it can be divided in three categories.

Peers: they are all other farmers who with the interviewee interact. They can be friends, neighbors, members of a development group…

Advisor: they are from a company that can be providing services and goods or only services. For example, the "group for agricultural development" of the chamber of agriculture is animated by an advisor, he provides services only. On the other hand, the farming cooperative pay advisors who provides to farmers services and sell them goods (inputs for the farm).

Others: In this category, we name the common ones which are internet, magazine and family. "other source" of this category can be a lot of different things such as books, conferences, equipment companies…

With the Peers and the Advisor, different way of behaving can be highlighted. Moreover, we can define different function accorded by the farmer to the other actor.

Behavior toward peers

Selective: He communicates with a precise kind of farmer who can be friends or peers who have the same particular practices as him. There is a real notion of choice in the peers who with he interacts.

Restrictive passive: More often the interaction with peers is limited to the observation of their practices. He rarely talks with the others. Moreover, the number of farmers he interacts with is limited, often to his neighborhood.

Restrictive active: He interacts, either by talking or by observing, with a limited number of farmers. Those peers are often his neighbor.

Opened passive: More often the interaction with peers is limited to the observation of their practices. He rarely talks with the others. However, the number of farmers he interacts with is not limited to his neighborhood, some of them belong to groups that he belongs to (can be linked or not with agriculture).

Opened active: He interacts, either by talking or by observing, with a number of farmers that can fluctuate but that is not limited.

Function of peers

Compare: More often, when they interact, they compare either the results (more often yields) or the practices observed in the neighbor's fields (more often about spraying).

Get specific information: They interact with other farmers with a defined objective. Usually they go to specific people who have particular information on a defined topic which is often the same.

See something else: They want to see what others are doing differently. Which kind of other practices, which other crops… They are interested in the results of those practices and can eventually consider copying it. It can be about input management, agronomy, economy…

Share : Those farmers usually have a lot of knowledge about a specific topic (direct-seeding, crop diversification…) and like to share and teach to others. They also find interesting to discuss or debate with others.

Form of advice

Personal: The more often, when the farmer needs an advice he directly calls the advisor from GDA or the SSR.

Group meetings: The more often, farmer gets information by going to group meeting. It can be regular group meeting or specific group meeting focusing on a defined topic.

Technical notes: The more often, farmer gets information by reading technical notes. It can be regular technical nots or specific ones focusing on a defined topic.

Function of the advice

Get prescription: The farmer does no feel at ease or is not interested in the management of the farm. When there is a contact with the SSR or the advisor he wants him to tell doses and development stages for use of plant health product application. This is a kind of complete delegation to decision linked to plant health products.

Reminder: The farmer is at ease managing the farm but he always needs a reminder to comfort his decision. Most of the time it is about plant health product (doses, development stages, homologation….).

Solve a problem*:* The farmer is at ease managing the farm but when he faces a problem he had never face before or when he is not sure about something, he asks the advisor or SSR. Most of the time the information concerns plant health product (doses, development stages, homologation….)

Improve specific practices*:* The farmer is at ease managing the farm but there are some specific practices that he would like to improve (plant healt product use, cover crop, tillage…) to meet specific objectives. When he goes to the advisor or SSR, he wants to get information on those specific practices.

Improve in general: The farmer is at ease managing the farm but feels the need to evolve for different reasons (economic, personal,…). When he goes to the advisor or SSR he wants to discover new practices that he already heard about or not in order to adopt the ones which fit him the best.

Appendix 10 - Grid of analysis, farmers' attitude toward crop diversification

Farm.	Diversification is positive because…	Diversification is negative because…	I will diversify my system only if…
		B0	
1	Leguminous crop bring nitrogen to the system It helps "cleaning" the fields from weeds	It increases the workload and creates new working periods which can superpose with tasks in the vineyard It changes habits It requires new knowledge	The new crop is as profitable as rapeseed I don't have to work with any other collector than mine I can introduce the crop on a consequent part of my farm for logistical aspects
8	It decreases rapeseed proportion in the rotation It could decrease herbicide use It could give the opportunity to apply a wider range of molecules	It creates a need for new marketing solutions It requires new equipment It is hard to find a crop which is adapted to local soil and climate conditions	The other do it before and succeed I am forced t by the law
11	It could improve weed management		The new crop is as profitable as rapeseed The new crop is as profitable as spring barley I can introduce the crop on a consequent part of my farm for logistical and financial aspects

12	It could give the opportunity to apply a wider range of herbicides It could decrease herbicide use	It is hard to find a crop which is adapted to local soil and climate conditions	The others do it before and succeed We find a crop that yield under our soil and climate conditions I can get new lands for logistical aspects
13		It is more complicated and I am too old It is hard to find a crop which is adapted to local soil and climate conditions	My cooperative propose a crop that possible to crop under our soil and climate conditions and is profitable
B1			
4	It mimics natural mechanisms It could decrease herbicide use It could decrease fertilizer use	It is hard to see further than the annual gross margin It is more complicated It is not obviously profitable It is hard to find a crop which is adapted to local soil and climate conditions	I face an agronomic issue A living mulch is considered as diversification The others do it before and succeed It is profitable I can introduce the crop on a consequent part of my farm for logistical aspects

14	It could decrease dependency toward crop buyer It could decrease herbicide use It could give the opportunity to apply a wider range of herbicides Cereal prices are currently too low	It is hard to find a crop which is adapted to local soil and climate conditions It creates a need for new marketing solutions	The buyer would accept that I sell him a mix of different crops There is a real beneficial effect that is proved I had more time to research
20	It is beneficial for the soil It could give the opportunity to apply a wider range of herbicides It brakes weed cycle It reduces input use	There is a lake of buyers for new crops It is more complicated in terms of interventions It is hard to find a crop which is adapted to local soil and climate conditions	My farm was less fragmented

B2			
2	It is an alternative to rapeseed which is better than implanting wheat two consecutive years It could improve weed management	It is more complicated in terms of logistic It is hard to find a crop which is adapted to local soil and climate condition It decreases annual grow margin It creates a need for new marketing solutions It changes working periods	I face an agronomic issue
6	It brakes weeds cycle and can thus solve weed resistance issue It staggers the workload	As observed on peers' farms, it is irregular It is technically more complicated There apparently no economic advantage It requires new equipment	I am forced to by the law
15	It can solve agronomical issues faced under little diversified cropping systems	It is hard to find a crop which is adapted to local soil and climate conditions	

18		It is hard to find a crop which is adapted to local soil and climate conditions It increases workload and thus induce a reduction of efficiency	
		B3	
3	It stagger harvesting periods It preserve soil nutrients It could give the opportunity to apply a wider range of herbicides		I earn enough money with the vineyard
5	It improves weed management It can increase annual gross margin It decreases the risk It staggers the workload It increases biodiversity It improves soil quality It is exciting		

7	It improves weed management by breaking weed cycles It is rewarding, professionally, technically , personally and in terms of agronomy It decreases the risk It staggers the workload	There is a lake of buyers for new crops on the territory (and not in the North) It requires time and increases workload It needs to change practices	
9	It is both an agronomical and chemical solution fo improve weed management It decreases the risk It can decrease charges	It increases the workload It introduces new constraints It needs reflection	I can feed the cattle with the crop in case of yield issue
10	It is an alternative to rapeseed in drained plots	It increased the workload, even more when small surfaces are concerned	
17	It can decrease herbicide use Leguminous bring nitrogen to the system It improve soil quality	It if requires different equipment	It has an interest for direct seeding It is profitable It is easy to implement

19	It could improve weed management It decreases the risk It could improve diseases management It could be a solution to yield cap It could increase macro and micro biodiversity It staggers the workload	If it requires new equipment My peers experience low yields with new crop the few last years	I can feed the cattle with the crop in case od yield issue

Appendix 11 - Farmers' experience and curiosity toward low-input crops

		Trial		Quoted spontaneously		Quoted after the list	
Crop	***Latin name***	**Nb**	**%**	**Nb**	**%**	**Nb**	**%**
Sunflower	***Helianthus annuus***	14	74%	19	100%	0	0%
Spring barley	***Hordeum vulgare***	14	74%	15	79%	0	0%
Winter pea	***Pisum sativum***	10	53%	15	79%	0	0%
Spring pea	***Pisum sativum***	9	47%	13	68%	0	0%
Broad bean	***Vicia faba***	8	42%	12	63%	1	8%
Corn	***Zea mays***	8	42%	12	63%	0	0%
Hemp	***Canabis sativa***	2	11%	9	47%	2	15%
Alfalfa	***Medicago sativa***	6	32%	8	42%	4	31%
Oats	***Avena sativa***	5	26%	6	32%	5	38%
Clover	***Trifolium***	3	16%	5	26%	2	15%
Lentil	***Lens culinaris***	2	11%	4	21%	2	15%
Buckwheat	***Fagopyrum esculentum***	2	11%	3	16%	2	15%
Soy	***Glycine max***	0	0%	3	16%	3	23%
Sorghum	***Sorghum bicolor***	3	16%	2	11%	5	38%
Flax	***Linum usitatissimum***	1	5%	2	11%	3	23%
Chick pea	***Cicer arietinum***	1	5%	1	5%	2	15%
Cocksfoot grasses	***Dactylis***	1	5%	1	5%	3	23%
Common vetch	***Vicia sativa***	1	5%	1	5%	2	15%
Pearl millet	***Pennisetum glaucum***	1	5%	1	5%	1	8%
Common sainfoin	***Onobrychis viciifolia***	0	0%	0	0%	5	38%
Lacy phacelia	***Phacelia tanacetifolia***	0	0%	0	0%	1	8%

Appendix 12 - Farmers' opinions about low-input crops

Table 1 - Sunflower (19 ; 100%)

	Experienced (14)		Inexpert (5)	
	Positive	Negative	Positive	Negative
Inputs	3		2	
Low risk	1			
Rotational effet			1	
Landscape			1	
Working period	2	3		2
Margin	2	1		
Varieties	1	1	1	
Equipment		2		4
Birds		4		1
Soil potential		2		1
Yield		4		
Cost of seeds		1		
Weeding		1		
Need for cover crop				1

Table 2 - Winter pea (15 ; 79%)

	Experienced (10)		Inexpert (5)	
	Positive	Negative	Positive	Negative
Rotational effect	2			
Present on territory			1	
Low risk			1	
Harvesting		3		1
Climat		3		1
Aphanomyces euteiches		2		1
Absent on territory		1		1
Soil		1		1
Yield		2		
Margin		1		
Autumn crop				1

Table 3 - Spring pea (13 ; 68%)

	Experiences (9)		Inexpert (5)	
	Positive	Negative	Positive	Negative
Rotational effet	2			
Present on the territory			1	
Margin	1	1		
Harvest		5		2
Soil		4		1
Aphanomyces euteiches		4		1
Yield		2		
Climate		1		
Working period		1		
Risky				1
Landscape				1

Table 4 - Broad bean (13 ; 63%)

	Experienced (8)		Inexpert (5)	
	Positive	Negative	Positive	Negative
Rotational effect	2		1	
Easier to harvest than pea	2		2	
Working period	1			
Margin		2	1	
Soil		1		1
Yields		1		1
Climate		4		
Market opportunity		2		
Varieties		1		
Insecticide		1		
Absence				2

Table 5 - Corn (12 ; 63%)

	Experienced (8)		Inexpert (4)	
	Positive	Negative	Positive	Negative
Soil	2		1	1
Weeding	2			
Varieties	1			
Yield	1	1		
Harvest		1		1
Margin		3		
Equipment		2		
Game		2		
Climate		1		
Difficulty		1		
Disapearance				1

Table 6 - Alfalfa (12 ; 42%)

	Exerienced (6)		Inexpert (6)	
	Positive	Negative	Positive	Negative
Inputs	1			
Rules	1			
Rotational effect	4	1	4	
Weeding	1	1		
Market opportunity		2		3
Yields		2		1
Logistic		2		
Perennial		1		
Soil				1
Harvest				1

Table 7 - Hemp (11 ; 47%)

	Experiences (2)		Inexpert (9)	
	Positif	Négatif	Positif	Négatif
Inputs	1		1	
Low risk			2	
Weeding			1	
Price		1	1	
Rotational effet	1	1	1	
Soil	1		1	1
Equipment		2		7
Working period		1		4
Contracts		1		2
Yields		1		1
Margin		1		
Adaptation to direct seeding		1		
Disapearance				1
Harvest				1
Pest and diseases				1

Table 8 - Oak (11; 32%)

	Experienced (5)		Inexpert (6)	
	Positive	Negative	Positive	Negative
Rotational effet	2			
Inputs	2			
Low risk			2	
Market potentiel	1	1		3
Yields	1	1		1
Margin		1		
Cattle use		1		
Disapeared				1
Climate				1
Harvest				1

Norwegian University
of Life Sciences

Postboks 5003
NO-1432 Ås, Norway
+47 67 23 00 00
www.nmbu.no