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Researchers, advisors and growers working together to design monitoring methods for functional agro-biodiversity

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Abstract: *The value of functional agro-biodiversity (FAB) for favoring natural pest regulation and then reducing pesticide use in fruit production is generally acknowledged. Many fruit growers try to favor FAB through different technics (diversified hedges, nesting boxes…) but they often lack of means to evaluate how their actions may indeed contribute to FAB. In this context, our research project aimed at developing FAB monitoring methods in order to help fruit growers to modify their practices and enhance the performance of natural enemies to reduce pest pressure.*

To do so, we adopted collaborative research methods which allowed us to make some adjustments in our research question and our objectives. We realized questionnaires, interviews and organized workshops with growers and advisors to understand their needs and practices, and involved them in the design of FAB monitoring methods. Our development-driven approach progressively led us to adjust our research focus and research objectives. We started our research process with the idea of producing FAB monitoring methods to enhance one specific service: natural pest regulation. We finally ended in producing a diversity of FAB monitoring programs adapted to a diversity of use and a diversity of targeted services.

On the basis of our experience, we discuss the conditions for developing collaborative and development-driven research. We especially show that this kind of research requires having flexible research objectives which can change over the time. It also requires long term research process to explore wide areas of interests for researchers and practitioners and to stabilize the research objectives.

Keywords: *fruit production, functional agro-biodiversity, collaborative research, development-driven approach*

Introduction

The value of functional agro-biodiversity (FAB) for favoring natural pest regulation and then reducing pesticide use in fruit production is generally acknowledged. FAB is a promising means to reduce the use of pesticides (Simon et al., 2010). To augment natural enemies of insect pests, ecological infrastructures should be maintained or improved as these are the places in and around the orchard providing beneficial insects with food, habitat and overwintering sites. Examples are hedgerows, flower strips, patches of wild vegetation (Boller et al., 2004). Though the regulating effect of FAB-structures on pests is scientifically proven (Zehnder et al., 2007), and even acknowledged by fruit growers, its implementation in practice is still scarce (Home et al., 2014). One reason that can explain this low development of FAB technics is that growers often lack information about how their actions may indeed contribute to FAB and to pest regulation, especially given the strong dependence of the natural processes on local conditions. Indicators about habitat provision, abundance or diversity of natural enemies do exist, but they don't provide any guarantee for effective pest regulation (Demestihas et al., 2017).

In this context, we aim at creating monitoring methods to improve management of FAB in order to help fruit growers to modify their practices and enhance the performance of natural enemies to reduce pest pressure. However, as we adopted a development-driven approach (Okali et al., 1994) and as we know that growers can have other expectations towards FAB

than pest regulation such as diversification of their source of income, conservation objectives, aesthetics or recreational benefits (Gurr et al., 2003), we developed an exploratory collaborative research process which would allow us to make some adjustments in our research question and our objectives.

As it has been the case in different fields such as in the organizational world (Greenwood et al., 1993), social work (Bradbury & Reason, 2003) or human health (Cornwall & Jewkes, 1995), the agricultural field developed research methods to facilitate interactions and knowledge exchanges between the researchers and the potential users of the research results (e.g. Chambers & Ghildyal, 1985; Farrington, 1989; Lacy, 1996; Lyon et al., 2011; Röling & Jiggins, 1994). In parallel, debates about the use and results of these methods emerged. Years later, the polarized debate on the value of participatory research as a scientific method has been replaced by a discussion about the potential of collaborative research (Neef & Neubert, 2011): about shortcomings (Baars, 2011) and modalities of collaboration between scientists and growers (Carolan, 2006). Among them, several studies point out the processes of social or collective learning occurring between researchers and growers involved in collaborative research (Bruges & Smith, 2009; Ingram, 2008; Schneider et al., 2009). However, less attention has been paid to the "researchers' side" and to their use of stakeholders' input in their research (Jolibert & Wesselink, 2012). Only a few studies explicitly allow to see the adjustments in the research questions or research objects which occur (Eshuis & Stuiver, 2005; Hazard et al., 2017; Prost et al., 2017; Steyaert et al., 2007) or which should have occurred (Eksvärd, 2010) and discuss about the conditions favouring these adjustments.

Therefore, the objective of our communication is not to present the results of the project concerning the FAB monitoring methods coming from our interviews and workshops[1], but rather to present the results of a self-reflection about our approach and results: we want to show how our development-driven approach progressively led us to adjust our research focus and research objectives. In order to do so, our communication will present the methods we used to collect users' needs and perceptions about FAB, the adjustments we did to integrate them and the results that we produced. We will finally discuss the specificities and limits of collaborative research methods according to our experience.

Methods to understand users' needs concerning FAB monitoring methods

Several studies aims to understand the motivations of growers for engaging in biodiversity conservation actions that is to say ***why*** they would engage in biodiversity conservation (e.g. Home et al., 2014; Pannell et al., 2006; Siebert et al., 2006; Wilson & Hart, 2000). In our approach, we consider ***functional*** agro-biodiversity and we adopted a pragmatic point of view. That is to say that we first focused on advisors and growers' practices and knowledge (what they already do or know for favoring FAB) and on ***how*** they currently manage biodiversity and only then, we tried to develop monitoring methods adapted to what they already do. Thus, we adopted an approach which aims at contributing to the empowerment of growers through learning processes and to their self-reliance vis-à-vis formal research and extension institutions (Sumberg et al., 2003). The adoption of this approach has been favored by the fact that some researchers of our team were little familiar with the specificities of pest regulation in orchards. Therefore, they were not so much motivated by the production of scientific knowledge about pest regulation in orchard but more by the production of a facilitation process to develop knowledge corresponding to users' needs.

To achieve that, we combined different qualitative methods in order to realize a triangulation and strengthen our results (Seale, 1999). We realized questionnaires and semi-directive interviews which are some of the classical tools of qualitative inquiries and which help us to understand the perception of FAB of fruit growers and advisors. We also organized

[1] These results will be presented in several forthcoming papers.

workshops inspired by the Participatory Action Research (PAR) tradition (Fals-Borda & Rahman, 1991; Reason & Bradbury, 2001) involving fruit growers and advisors in order to understand their current practices and their needs with the aim of ensuring results relevance for users and to involve them in the design of FAB monitoring methods.

Exploratory surveys

First, in 2014, we realized an exploratory survey during a French national organic farming event dedicated to fruit production (Tech&Bio 2014) welcoming that year about 1000 visitors. This exploratory survey (Cardona & Dufils, 2014) was based on a questionnaire composed of closed-ended and open-ended questions and aimed at assessing growers and advisors' perceptions of the notion of "functional agro-biodiversity" ("biodiversité fonctionnelle" in French). We asked them if they already heard about this expression, if they were familiar with the concept, if they developed specific practices to enhance FAB, and if yes, which ones. After an entire day on the event, the two surveyors questioned 25 people randomly chosen: 18 fruit growers and 7 advisors during 15 to 30 minutes each. As the event was dedicated to organic farming most (15) of the questioned fruit growers were organic.

Semi-directive interviews

In 2015, we carried out semi-directive and comprehensive interviews in France with 11 fruit advisors from the different French regions of fruit production and 19 fruit growers from south-east, north-west and north-east of France. The sampling aimed at including participants more or less convinced by the benefits of functional biodiversity for the management of orchards but also participants with different degree of experience concerning the management of functional biodiversity. These interviews aimed at appreciating their perception and skills about FAB and the techniques they implement to favour it (Fernique, 2015). The objectives were to deal with the perceptions of FAB in depth but also to better understand the different management of FAB in order to identify different categories of perceptions and management of FAB. Our hypothesis was that the identification of current different categories of perceptions and management of FAB would help us to produce monitoring methods adapted to a diversity of users.

Workshops

From winter 2016 to winter 2017, we carried out a participatory action with a group we are used to work with[2], gathering advisors (6), fruits growers (7) and some researchers working in experimentation fields (4). This group has been already involved in several qualitative inquiries about the management of orchards and is usually interested to participate in research processes.

This action has been organized in three steps. First, a workshop aimed at revealing perceptions of FAB and the links between their management practices and FAB. To do so, the participants of the workshop were asked to answer the question "what is functional biodiversity for you?" Each person had to provide one idea and then yield the parole to the next person, until no one had anything more to say. Responses were displayed progressively for all to share. Then they expressed the links between practices and FAB by building a two-column table gathering management practices influencing either positively, either negatively FAB, according to their knowledge. Finally they shared the monitoring techniques they knew, and extension services presented some more. Each person then had to choose, among these techniques, those they were ready to try and apply during the next growing season.

Second, during the growing season, phone interviews were carried out to obtain first feedbacks from the workshop participants on the use of the methods or on the reasons why they finally did not apply the method they had chosen. The objective of these phone calls was to prepare the next workshop in adapting its outline to what participants did during the growing season.

[2] This group called "Vergers Durables" is a francophone group gathering fruit growers, advisors and researchers involved in experimentation from France, Belgium, Swiss and Spain. During the last ten years, the group used to meet once a year to exchange about new technics and design processes of sustainable orchards.

Third, during the following winter 2017, a workshop gathering the same participants aimed at (i) collecting and discussing their feedbacks on the methods and (ii) design FAB monitoring programs adapted to each perceptions of FAB according to the "profiles (or categories)" defined thanks to the semi-directive interviews described above.

Appropriate FAB monitoring methods

Diversity of perceptions of FAB

Our exploration of FAB perceptions started with the exploratory survey we carried out on an organic farming event dedicated to fruit production. 20 people on a total of 25 questioned already knew the term: all the questioned advisors and 13 fruit growers. Most of them think about FAB in terms of something which "benefits" to the orchards or which is "useful" or "helpful" (14 people) . For some growers (3) it is something "important" and even "necessary" especially in organic farming systems. In their definition of FAB most of them talked about "beneficial insects" favoring "pest regulation". Only two of them adopted a more systemic point of view referring to the "ecological balance" of the orchard or the link between "farming" and "nature". At this point of our research, and according to the answers of the people questioned, it seemed that considering FAB under the prism of pest regulation could correspond to fruit growers and advisors' expectations.

The semi-directive interviews (Fernique, 2015) produced similar results concerning the awareness of the term FAB: 10 advisors among the 11 interviewed knew the term and said that they used it regularly. 14 fruit growers among the 19 interviewed knew the term; three fruit growers never heard about the term and two said that they already heard about the term but didn't really know its significance. Advisors, as well as fruit growers, gave the same kind of definition of the term, which refers to interactions between the "nature", the "wildlife" and "the orchard", "the cultivation", "the agro-system". All the interviewed persons mentioned the pest regulation service provided by FAB. When we questioned them about the technics they used to favor FAB and especially about the interests of these technics, they mentioned several different services beyond pest regulation: environmental protection (as a contribution to global biodiversity protection, decrease of pollution…), welfare at work (pleasure at work, diversification of work task, reduction of work time via the reduction of pesticides application), aesthetic (beautiful landscape), pollination, source of economic benefit (via the diversification of production or reduction of pesticides use), communication (to make visible the state of the orchard to consumers coming on the farm), human health (through the reduction of pesticides use), heritage conservation (conservation of emblematic species).

The workshop also revealed a diversity of perception of what is FAB. The initial question we asked in the workshop "what is FAB for you?" produced 44 answers from the 17 participants. The answers can be grouped into 4 main categories: FAB definition (14), services (10), management (16) and observation or evaluation (4). FAB definitions refer to different lexical fields related to ecosystems ("trophic networks"), social relationships ("meeting place between man, animal and plants") or cropping practices ("flower strips"). Among the 10 FAB services listed by the group, only three explicitly refer to pest regulations. The remaining ones (7) either state that FAB fulfils a diversity of goals without naming them, either name one of those other services ("pleasant landscape", "builds the global farm balance"). Most of the answers in the FAB management group refer to its complexity or scale issues ("needs an ecosystem understanding"), only three refer to its management ("it can be driven, we can act, influence it") among which only one probably refers to natural pest regulations ("mastering the balance of FAB") but without really mentioning them. The last group, FAB observation, has four answers, two of them pointing to the effects of FAB on pest regulations through the observation of plant health or pesticide use reduction.

Some of the answers clearly pointed to a vision of FAB as a management tool that can be used to reach the orchard health goals. However, it clearly appears that the pest regulations and the role of FAB in maintaining the health of the orchard are far from being the main perception and concern of the participants of the workshop. FAB is on the contrary perceived

as a very complex object made of complex interactions among living organisms and between them and their environment. It is also perceived as multifunctional (which probably reinforces its complexity) and sometimes as "hard to observe", hard to grasp ("the grower must be humble in front of FAB") and almost as a hidden process operating by its own in the farm or plot ("free service of nature for us to understand").

This set of inquiries about FAB perceptions broadens our understandings of what is FAB for advisors and fruit growers. As already observed for the notion of "biodiversity" (Herzon & Mikk, 2007; Kelemen et al., 2013; Noe et al., 2005), there is a diversity of perceptions of what is FAB. Therefore, it appears that if we want to produce research results which correspond to fruit growers and advisors ideas and needs, we cannot only consider pest regulation services of FAB. We have to adopt more holistic approaches to consider other FAB services and uses.

Diversity of objectives and uses of monitoring methods

During the workshop, when we asked the participants what FAB monitoring methods do they already use or would they use in the future, they shared 15 monitoring methods and five modalities of observations (ways of arranging the observations according to a given goal, e.g. repeat the observations at increasing distances from a hedge to evaluate the hedge effect and its limits), presented in the table below:

Table 1 Monitoring methods and modalities of observation proposed during the 1st workshop

Monitoring methods	**Modalities of observation**
Observation of deficiency on leaves	Organizing observations in time, before and after the installation of an ecological infrastructure
Traps for invertebrates	Comparing two farming systems
Measuring soil respiration	Organizing observation according to a gradient of distance from ecological infrastructure
Earthworms counting	Identifying preferential zones of observation on the farm
Earwigs counting in traps	Observation of insects and birds under hail nets
Egg predation cards	
Beating	
Building bird nests and insect shelters	
Trapping insect for destruction	
Barber pitfall trap	
Visual observation of beneficial fauna	
Observation of flora	
Observation of fruit damages	
Counting of insects after use of insect sweep net on flower strips	
Visual observation of soil	

The list of proposed monitoring methods confirms that there is a diversity of perceptions of what is FAB, but also of its services. The proposed observations concern the conditions of pest regulation ("observation of fruit damages", "egg predation cards"), the presence of beneficial fauna contributing to pest regulation, the presence of global biodiversity ("measuring soil respiration", "earthworms counting", "Counting of insects after use of insect sweep net on flower strips") and the presence of food for beneficial insects ("observation of flora") or the use of habitats ("observation in bird nests of insect shelters"). We had difficulties

to narrow the discussion about the "monitoring methods", this reveals that it seems actually difficult to separate the monitoring operations from actions to maintain or attract FAB.

Then, we asked them to choose monitoring methods that they would use or test during the next growing season. Two propositions were not chosen at all (measuring soil respiration and organizing observations in time, before and after the installation of an ecological setup). The others were unequally chosen; the most preferred being direct observation, beating, habitat installation to facilitate observations, earwigs counting in traps, beating and flora observation. Again, it must be noted that these methods do not target pest regulations only. They also aim at evaluating the habitats for auxiliaries for example.

After this first workshop, we sent them by mail and e-mail information and protocols corresponding to the monitoring methods they chose at the workshop. During the growing season, we called them by phone to ask them if they used them and how. We had a diversity of answers about their use of the monitoring methods. Some participants didn't make any observation although they thought about it. Several made some observations but without a protocol or without noting what they observed. Some participants used the monitoring methods they chose according to the given protocol. Finally, others used the monitoring methods but adapted the protocol to their habits or needs. To explain what they did or what they did not, participants proposed different justifications. These justifications were intrinsically linked to their different perceptions of FAB, but also to their modes of FAB managements.

The semi-directive interviews had already helped us to understand that advisors and fruit growers develop different kind of FAB managements, which are more or less interventionist (Fernique, 2015): some of them observe positive or negative interactions between the orchard and its environment without trying to act in favor or against, others try to conserve the existing biodiversity and favor vegetal and animal biodiversity in their orchard and its environment to develop FAB, others try to favor FAB in their orchard and its environment only with crops. The phone calls completed this first analysis of the different FAB management: we learned that some fruit growers delegated the observation to their workers or to a hired specialist such as an intern or even a researcher, others were more in a "laisser-faire" (let-it do) approach and deliberatively did not make any observation, others were uncomfortable with the idea of writing note while others in contrary were at ease with a quantified monitoring. This led us to identify different kind of attitudes towards FAB.

4 main attitudes[3] towards FAB

This allowed us to identify 4 main attitudes towards FAB referring to a combination of perceptions and mode of management of FAB:

- the "passive attitude" based on the observation of positive or negative interactions between the orchard and its environment without any attempt to interact either by ignorance or because they are not judged significant for the management of the orchard,
- the "naturalist attitude" based on conservation, restoring and establishment of a diversity of plants and animals in the orchard and its close environment,
- the "regulation attitude" based on an explicit and strategic use of FAB to regulate specific pests in combination with other methods of plant protection,
- the "multifunctional attitude" based on the use of FAB to regulate pests at the farming system scale and also to reach other objectives (aesthetic, diversification etc.…).

These attitudes do not correspond to person's profile. One person can adopt different attitudes in regard to different biodiversity compartments or in regard to the different techniques they implement. Attitudes can also vary over time: for example, a fruit grower can

[3] "Attitude towards FAB" refers here both to the perceptions and the modes of FAB management of interviewed fruit growers and advisors.

have a naturalist attitude in regard to his hedges for a time and then adopt a multifunctional attitude when he decides to plant fruit trees in it.

Monitoring programs adapted to FAB attitudes

On the basis of these four perceptions of FAB, corresponding to different perceptions and management of FAB, we decided to design, in collaboration with the participants of the workshops, monitoring programs (i.e. combinations of monitoring methods) which would be adapted to these attitudes towards FAB. Our objective was to determine for each attitudes what monitoring methods would be recommended, at what time and at which frequency the monitoring methods would be used, who would use the monitoring methods (the grower, a worker, an advisor…), what kind of notation would be recommended and what knowledge or tools are currently missing. This workshop session produced four monitoring programs presented in the table below:

Table 2 Monitoring programs adapted to attitudes towards FAB

	Passive attitude	**Naturalist attitude**	**Regulation attitude**	**Multifunctional attitude**
What monitoring methods would you recommend?	Someone adopting a passive attitude would never use monitoring methods or else you can get them to realize that there is life in their orchard: first, you give them a formation about insects' identification and then invite them to make 2 or 3 observations without notation, for example visual observation of aphids.	A biodiversity census in the grower's orchard with regular observation during the season, aiming at biodiversity compartment or a specific animal he is interested in. Then, you can ask him to look at the regulation phenomenon. For example, if a grower is interested in bats, ask him to do a census of bats in his orchard, ask him to look at damages made by codling moth and then try to make the link between the presence of bats and the management of codling moth.	Predation cards, observation of beneficial insects or birds to determine when to spray, observation of couple pest/beneficial insects or birds	The multifunctional approach supposes to get a "global vision" of FAB, importance of being able to invite other persons to work on the orchard. Monitoring methods must be applied at the scale of the farm and not only at the scale of the plots.
At what time of the year/ at what frequency would you use them?	/	Regularly but the importance of starting the census trained ½ day by a technician to explain how to do the census.	It is important to start at the beginning of the growing season. Observation linked to pests and beneficial lifecycles. Regularly and over several years to be able to determine thresholds after a while. Those thresholds will be specific to each orchard and will be approximate thresholds.	Every time it is possible during the year.
Who would use the monitoring methods?	/	The growers	Workers in charge of spraying interventions or technician/advisor	Someone working with a multifunctional approach can/should attract lots of researchers and students who can do the observations on his/her orchard

	Passive attitude	Naturalist attitude	Regulation attitude	Multifunctional attitude
What kind of notation?	/	pictures	Writing notation adapted to field needs and to keep in memory the observation and then define thresholds	Precise notation for several beneficials and biodiversity compartments. Importance of a notation on several years, of having an "historical" notation.
What knowledge/tools are missing?	/	Knowledge about how to organize the observation: we can imagine that different persons (grower and workers, or different growers working on several orchards) could be in charge of the observation of different biodiversity compartment and then they pool their observations to get a global vision of the FAB in the orchard.	/	One person cannot get all the skills to monitor the all the produces services, the grower should be able to find the resource-persons useful to help them to observe the different produced services

Specificities and limits of our comprehensive and collaborative method

Our development-driven approach aiming at producing monitoring methods adapted to users' needs led us to progressively adjust our research objectives. Doing this we follow Eksvärd recommendations concerning research approach for supporting transition towards ecological agriculture (2010), when she said: "*Within a 'participant driven' PLAR [Participatory Learning and Action Research] approach, the farmers would have been invited to explore a wider area of interest, like organic vegetable production or nutrient management in organic vegetable production. The focus would have been developed thereafter on the basis of shared interests between the participating farmers as well as the researchers."(p66).* In contrary of what we initially thought, it seemed impossible to ask to growers or advisors to only consider the pest regulation services of FAB. Advisors, fruit growers and researchers working in experimental fields not only consider one service or one compartment of FAB, they consider the farming system as a whole, which combines a diversity of farming practices producing a diversity of services. In respect to our development-driven approach, it appeared necessary to take in account all these dimensions. We started our research process with the idea of producing FAB monitoring methods to enhance natural pest regulation. We finally progressively integrated a diversity of perceptions, kind of management, uses around FAB, expressed by the people we worked with and ended in producing a diversity of FAB monitoring programs adapted to a diversity of use and a diversity of targeted services. Therefore, our development-driven approach progressively led us to adopt a more holistic approach of our research objectives. Neef and Neubert (2011) showed that collaborative research is more adapted for system oriented holistic approaches than for reductionist ones. What we learned with our experience is that collaborative research can also lead researchers to shift from a reductionist approach to a system holistic one. This specific shift from reductionist to a more holistic approach has certainly not only been caused by our collaborative methods, but also by our research object. Biodiversity-based agriculture is actually considered as context-dependent and uncertain system, complex to be managed and *"which requires implementing a more systemic and holistic view of agricultural systems"* (p 1275) (Duru et al., 2015). However, it is clearly our collaborative and development-driven approach that led us to realize an epistemic adjustment in itself (change in the research objectives). Practicing this kind of research requires then to have flexible research objectives, which can change over the time.

This kind of research can have some limits. It implies a long term process. Long time is needed to explore wide area of interests for researchers and practitioners (growers, advisors, etc…) and to stabilize the research objectives. Then, it implies to retain all the participants of

the collaborative research process sometimes during several years. Finally, it also questions our system of research management mostly based on short-term research projects.

Moreover, having flexible research objectives is not always possible for researchers: first simply because of their skills, researchers or research team cannot always easily adjust their research object, but also because of their personal research agenda and career. In our case, our flexibility has been facilitated by the fact that our research team was composed by two agronomists and a social scientist who can then cover a wide range of research questions, but also because one of the agronomist and the social scientist were neither specialist of pest regulation nor of orchard and they were consequently more interested in the facilitating process than in the initial research objective. However, this last point can have its own limits. On focusing on the facilitation of the process collaborative research and on users' needs; one can lose sight of the scientific validity of the research results. Our own research results, the monitoring programs, can be questioned from this point of view. The monitoring programs may be appropriate for users but what kind of information do they produce? Are the proposed observations really useful for FAB management in orchard? What about the interpretation of the made observations? These questions would surely deserve another long-term research project! ...

Conclusion

We started our research process with the idea of producing FAB monitoring methods to enhance natural pest regulation and we ended in producing a diversity of FAB monitoring programs adapted to a diversity of use and a diversity of targeted services including pest regulations but also conservation objectives, diversification of fruit production etc. We assumed that to create monitoring methods useful and appropriate to users' needs, we have to take in account the variety of knowledge, perceptions and interests about FAB. We adopted therefore a comprehensive approach based on questionnaires, interviews and workshops with French fruit growers, fruit advisors and researchers working in experimental fields. These methods allowed us to explore the diversity of perceptions of FAB but also the diversity of objectives and uses of monitoring methods. It appeared that it was impossible to limit FAB to a single service of pest regulation. This led us to identify four main attitudes towards FAB combining FAB managements and FAB perceptions and then, to design with them four monitoring programs adapted to the four attitudes. With this experience, we wanted to show how the collaborative research process combined with a development driven approach can progressively change research objectives of a research team.

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