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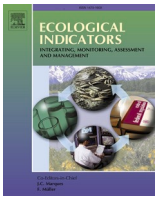

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ABSTRACT

The role of functional biodiversity for favouring natural regulation and reducing pesticide use in fruit production is generally acknowledged. Although a number of farmers attempt to favour biodiversity through different strategies (e.g. diversified hedges, nesting boxes), they often lack means to evaluate how their actions contribute in practice to functional biodiversity. We assumed here that to create useful and appropriate monitoring methods, it is necessary to take into account the variety of knowledge, perceptions and interests about functional biodiversity. To test our hypothesis, we adopted a comprehensive and participative approach based on interviews and workshops with farmers, advisors and field agronomists involved in apple orchard management. Our objective was to understand their different perceptions and uses of functional biodiversity and then, to design monitoring methods adapted to those perceptions and pre-existing uses.

Our findings revealed both a plurality of perceptions of functional biodiversity along with a diversity of objectives and uses of monitoring methods. Based on these results, we identified four main attitudes towards the management of functional biodiversity: the wait-and-see attitude, the naturalist attitude, the regulation attitude and the multifunctional attitude. These attitudes do not correspond to person's profiles, since one person can adopt different attitudes in regard to different biodiversity components or in regard to the different practices supporting biodiversity. In addition, attitudes can vary over time. The identification of these attitudes allowed us to design, with the workshops' participants, a guiding framework to create monitoring programs (i.e. combinations of monitoring methods) adapted to a variety of uses and targeted services.

1. Introduction

The intensification of agriculture plays a significant role in the decline of biodiversity since several decades (Benton et al., 2003; Green et al., 2005; Dudley and Alexander, 2017). The reiterative use of synthetic pesticides along with the simplification of the farming landscape has negative consequences on ecosystem services associated to biodiversity such as natural pest control based on predation by beneficial insects (Emmerson et al., 2016; Rusch et al., 2016; Humann-Guilleminot et al., 2019). Different measures have been proposed to reconcile agricultural production with biodiversity (see for example Tittonell, 2014). Among others, two main approaches with different objectives were developed in order to reach this reconciliation: the first approach relies on encouraging the involvement of farmers in biodiversity conservation whilst the second approach aims at improving the management of biodiversity providing services such as pest regulation or pollination – also called functional biodiversity – by farmers. Although some studies have analysed the impact of public measures along with the motivations of farmers for engaging in biodiversity conservation actions (Pannell et al., 2006; Siebert et al., 2006; Home et al., 2014), there is currently a lack of knowledge concerning how to translate such information into farming systems based on functional biodiversity (Duru et al., 2015).

Functional biodiversity is generally acknowledged as a promising mean to regulate pests and reduce the use of pesticides in orchards (Pfiffner et al., 2019; Simon et al., 2010; Zehnder et al., 2007). However, even when acknowledged by farmers, its implementation in practice is generally scarce (Home et al., 2014). One reason is that farmers often lack information about how their actions may indeed contribute to

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functional biodiversity and to pest regulations. Whereas indicators on the relationship between habitat provision and abundance or diversity of natural enemies do exist, it remains difficult for farmers to appreciate the effect of their practices on biodiversity (Gurr et al., 2003), especially to observe long-term effects such as the establishment of a diverse community of beneficial arthropods (Duru et al., 2015).

Our hypothesis is that the current indicators are not designed to be put in practice by potential users as it is also the case for many agricultural decision support tools (Cerf et al., 2012; Ditzler et al., 2018). Indeed, the benefits of biodiversity are generally measured at a societal or global scale and rarely ever at an individual farm's scale (Kelemen et al., 2013). To address this shortcoming, recent projects implemented simple indicators adapted to the daily farm management: for instance, FAO developed the Visual Soil Assessment which assesses soil components involved in its fertility and a protocol to detect and assess pollination deficits in crops (Bioagrinomies, 2008). Another example is the BIO-BIO project that aimed to develop biodiversity indicators for organic and low-input farming systems relevant and useful for stakeholders (Herzog et al., 2012). However, these indicators are not necessarily adapted to the diversity of relations between the actors involved in farm management (e.g. farmers, advisors, agricultural workers, field agronomists) and functional biodiversity. Several studies highlighted the multiple perceptions of biodiversity and advocate for "a plural value approach of biodiversity" (Kelemen et al., 2013). Gurr et al. (2003) as an example, provides data on the variety of expectations of farmers towards functional biodiversity, which range from pest regulation to diversification of their source of income and include conservation objectives, aesthetics or recreational benefits. Therefore, one great challenge to support functional biodiversity-based systems is to develop indicators and monitoring programs – that is to say combinations of monitoring methods – adapted to this variety of objectives pursued by the actors ensuring daily farm management.

In this study, we report on a collaborative research process aiming at producing a guiding framework to adapt monitoring programs of functional biodiversity to an array of perceptions and uses in order to facilitate biodiversity management in apple orchard farming systems. These monitoring programs rely on a combination of indicators and monitoring methods adapted to each person and are based on flexible protocols, which do not necessarily require written records or regular observations. The originality of our study lies in the fact that we adopted a pragmatic point of view building on actual practices and knowledge of farmers, advisors and field agronomists. We focused on what they already do or know to favour functional biodiversity and on how they currently manage biodiversity in order to develop monitoring methods. Because of this perspective, we chose to focus our study on organic and integrated apple production systems, known for relying on natural regulations.

2. Materials and methods

This study is based on a collaboration between different stakeholders in order to get a comprehensive approach, as broad as possible, of the potential perceptions and uses of functional biodiversity (Jackson et al., 2007; Brévault and Clouvel, 2019). With this aim, the study involved scientists from different disciplines (entomology, agronomy and sociology) and different actors directly involved in the management of apple orchard farming systems (farmers, agricultural workers, advisors and field agronomists), from different countries. Several qualitative methods were combined in order to validate and strengthen our results (Seale, 1999). We carried out questionnaires and conducted semi-structured interviews which are the classical tools of qualitative inquiries (Berner-Rodoreda et al., 2018) and which helped us to understand the various perceptions of functional biodiversity (the interview guides are available in Appendices). We also organized workshops inspired by the Participatory Action Research (PAR) tradition (Fals-Borda and Rahman, 1991; Reason and Bradbury, 2001) in order to understand the current practices and the needs of future potential users for relevant monitoring methods of biodiversity. All the collected data were analysed according to the principles of the inductive category development of the qualitative analysis content (Mayring, 2000) in order to allow emergent insights about the perceptions and uses of functional biodiversity. In this article, we use some quotations – which constitutes our raw material – to illustrate the data analysis process and to support the findings (Eldh et al., 2020).

2.1. French exploratory surveys about the perception of functional biodiversity

In 2014, we conducted an exploratory survey during a French national organic farming event dedicated to fruit production (Tech&Bio, 2014), welcoming about 1000 visitors. We predicted that the visitors of an organic fair would be more prone to develop uses of functional biodiversity. This exploratory survey was based on a questionnaire composed of close-ended and open-ended questions and aimed at assessing farmers and advisors' perceptions of the notion of "functional agro-biodiversity". We asked them if they had already heard about this expression, if they were familiar with the notion, if they developed specific practices to enhance functional biodiversity, and in such case, which ones. The answers were directly noted on the printed questionnaires by the surveyors who validated their potential written reformulation with the interviewee. During a full day of the event, the surveyors questioned 25 people randomly chosen out of which 18 were farmers and 7 were advisors. Each interview lasted from 15 to 30 min. As the event was dedicated to organic farming most (15) of the questioned farmers were organic producers.

In 2015, this first exploratory survey was complemented with semi-structured and comprehensive interviews in the different French regions of fruit production (South-East, North-West and North-East of France) with 11 fruit advisors and 19 farmers. We built the sample by combining two methods of sampling used in qualitative research (Patton, 2014): i) the criterion sampling involving to study all cases that meet the criteria predetermined by the research team ii) the heterogeneity sampling, involving to pick a range of cases which allows to document the diversity and to identify common patterns across the diversity. Based on our first exploratory survey, we identified two criteria of sampling 1) the degree of conviction about the benefits of biodiversity 2) the degree of experience concerning the management of biodiversity. In each French region, we contacted a diversity of advisors according to these criteria. Then, we use the method of snowball sampling (Goodman, 1961), and we asked the advisors previously interviewed, to help us to identify farmers corresponding to these criteria. This sampling included participants with different profiles identified by the advisors and confirmed during the survey: more or less convinced by the benefits of functional biodiversity and with different degree of experience concerning the management of functional biodiversity. These interviews aimed at appraising their perceptions and skills about functional biodiversity and the techniques they implemented to favour it. This sampling based on a diversity of profiles aimed to gain a deeper understanding of the different perceptions and management of functional biodiversity. Our hypothesis was that the identification of current different categories of perceptions and management of functional biodiversity would help us to produce monitoring methods adapted to a diversity of users. All the interviews were audiorecorded and entirely transcribed in order to realize a qualitative analysis of the content.

2.2. Workshops in 3 European countries: France, Sweden and Denmark

From winter 2016 to winter 2017, we invited farmers, advisors and researchers to participate in two rounds of workshops in three European countries (France, Sweden and Denmark)[1]. Each workshop gathered about 15 participants (50% were farmers, 25% were advisors and 25% were researchers). All the participants of the workshops were already involved in long-term research processes with the research teams of the different countries and were invited to participate to the workshops because they were identified by the researchers as key-knowledgeables and key-informants.

The organization of the workshop was inspired by the method of focus groups interviews. Focus group interviews is a research method in which a small group of people talk about topics selected for investigation under the guidance of a facilitator and which are frequently used within the interpretative paradigm as a qualitative method of data collection (Morgan, 1996). The focus groups interviews aim to let the participants interact with one another rather than with the interviewer only in order to favour the emergence of views on a bottom-up basis (Fallon and Brown, 2002).

Except for the addition of an initial question in France, the first round of workshops was similarly structured in the three European countries. The initial question in France, "what is functional biodiversity for you?" aimed at validating the first results of the exploratory surveys about the perceptions of functional biodiversity.

Then, in the three workshops organized in the three countries, we invited the participants to share the monitoring techniques they knew. The workshop ended with an engagement of the participants to use or test some monitoring methods they chose during the following growing season. During the following production season, we carried out phone interviews (about 20 min) with the French workshop participants, to obtain their first feedbacks on the use of the methods or on the reasons why they did not apply the method they had chosen. During the following winter of 2017, we invited the same participants to a second round of workshops in order (i) to collect and collectively discuss their feedbacks on the method they selected and (ii) to design functional biodiversity monitoring programs adapted to their needs.

Each workshop was audiotaped and transcribed. We carried out a qualitative and thematic content analysis for each workshop according to an inductive approach. We analysed the similarity of discourses across the three countries after which we considered them as robust results.

3. Results

3.1. Diversity of perceptions of functional biodiversity

Our results about functional biodiversity perceptions in the French context are based on the combined materials of the exploratory survey that was carried out during the professional event dedicated to organic fruit production, the semi-structured interviews and the first French workshop. The answers about functional biodiversity perceptions can be gathered into five main themes: functional biodiversity as interactions between nature and farming, relevance of functional biodiversity, services provided by functional biodiversity, management of functional biodiversity, observation and evaluation of functional biodiversity. This material is synthetized in the Table 1 below:

Our exploration of functional biodiversity perceptions started with the exploratory survey that was carried out during the professional event dedicated to organic fruit production. Twenty people out of the 25 questioned had already heard the term "functional biodiversity", respectively all the questioned advisors and 13 out of 18 farmers had awareness of it, while 5 were not familiar with the notion. Most of the people who had already heard about functional biodiversity thought about it in terms of something that brought *"benefits"* to orchards (14 people). In their definition of functional biodiversity most of them talked about *"beneficial insects"* favouring *"pest regulation"*. For some farmers (3) it was something *"important"* and even *"necessary"* especially in organic farming systems. Some farmers (2) also referred to a more systemic point of view mentioning the *"ecological balance"* of the orchard or the link between *"farming"* and *"nature"*.

The semi-structured interviews conducted in France produced similar results concerning the awareness of the term functional biodiversity: 10 advisors among the 11 interviewed knew the term and stated that they used it regularly. Fourteen farmers among the 19 interviewed knew the term; three farmers had never heard about it and two said that

Table 1
Synthesis of the answers to the question: "What is functional biodiversity for you"?

Themes	Representative Quotes		
	French exploratory survey	French semi-structured interviews	French workshop
Functional biodiversity as interactions between nature and farming	"ecological balance" [link between] "farming" [and]"nature"	Relationships between "nature", the "wildlife" and "the orchard", "the agro-system". "nature cultivation", "relationships between beneficial insects and pests", "interactions between plants", "balance in the orchard"	"trophic networks", "meeting place between man, animal and plants"
Relevance of functional biodiversity	"brought benefits", "useful", "helpful", "important", "necessary",	"Useful", "useful insects", "benefits"	"useful", "contributes to the autonomy of the agroecosystem",
Services provided by functional biodiversity	"beneficial insects", "pest regulation", "ecological balance"	"pest regulation service", "help the production and pest regulation"	"pest regulation service" and a diversity of other goals: "pleasant landscape", "pleasure in the orchard"
Management of functional biodiversity	/	"to preserve habitats for fauna"	Complex management: "needs an ecosystem understanding", Controlled management: "it can be driven, we can act, influence it" It should be "economically viable"
Evaluation of functional biodiversity	/	/	Difficulties of observation: "hard to grasp", "locally situated" Effects of functional biodiversity: "appreciated by its impacts on productivity and plant health", "reduction of pesticides use"

[1] During winter 2016, the workshops took place on 2016/01/18–19 in France, 2016/02/25 in Sweden and 2016/04/15 in Denmark. During winter 2017, the workshops took place on 2017/01/30 in France, 2017/03/16 in Sweden and 2017/03/21 in Denmark

they had already heard about the term but were not familiar with its meaning. Advisors, as well as farmers, gave a similar definition of the term, which refers to interactions between *"nature"* and *"the orchard"*. All the people interviewed mentioned the pest regulation service provided by functional biodiversity.

The discussion from the first French workshop also revealed a diversity of perceptions of what functional biodiversity represents to the participants. The question "What is functional biodiversity to you?" raised 44 answers from the 17 participants referring to different lexical fields related to ecosystems (*"trophic networks"*), social relationships (*"meeting place between man, animal and plants"*) or agroecological infrastructures (*"flower strips"*). Only three answers explicitly referred to pest regulation, and other services were mentioned such as aesthetic, welfare-to-work. Some answers mentioned the complexity of functional biodiversity management or scale issues and only three referred to a form of controlled management. In addition, few participants mentioned the difficulties of observing functional biodiversity and the necessity to evaluate its effects. Some of the answers clearly pointed to a vision of functional biodiversity as a management tool that can be used to reach orchard health goals. However, it clearly appears that pest regulation and the role of functional biodiversity in maintaining the health of the orchard are far from being the main perception and concern of the participants of the workshop. On the contrary, functional biodiversity is perceived as a very complex notion, made of a variety of interactions between living organisms and their environment. It is also perceived as multifunctional (which probably reinforces its complexity) and hard to grasp.

3.2. Diversity of objectives and uses of monitoring methods

Another objective of our study was to understand the diversity of objectives and uses of monitoring methods of functional biodiversity by the participants. The participants of the workshops of the three studied countries referred to a large variety of already existing monitoring methods. The Table 2 below presents all the methods cited by the participants during the workshop.

The list of proposed monitoring methods confirms that there is a diversity of perceptions of what is functional biodiversity, but also of its services. The monitoring methods cited by the participants to the workshops concern the efficacy of pest regulation, the presence of beneficial fauna contributing to pest regulation but also the presence of global biodiversity and the presence of food for pollinators or the use of habitats. When they mentioned "destructive traps" – meaning that the trapped insects rapidly died – (*"pan traps"*, *"pitfall traps*", "*light traps*", "*sticky traps*", "*water traps*"), discussions reveal the difficulty for the participants to separate the monitoring operations from pest management – especially concerning the use of light traps and water traps.

Table 2
List of proposed monitoring methods named by the workshop's participants.

	Proposed monitoring methods	France	Sweden	Denmark
Efficacy of pest regulation	Observation of leaf (pest damages)	X	X	X
	Egg predation cards	X	X	X
	Observation of fruit damage	X		
Presence of beneficial fauna contributing to pest regulation	Visual observation of fauna	X	X	X
	Beating samples	X	X	X
	Pan traps		X	
	Pitfall traps	X	X	X
	Suction sampling		X	
Presence of global biodiversity	Soil observation	X		
	Earthworms counting	X		
	Counting of insects after use of insect sweeping net on flower strips	X		
Presence of food for pollinators	Visual observation of flora	X	X	X
Quality of habitats	Visual observation in bird nests or insect shelters	X		
	Climate station			X
Destructive traps	Pan traps		X	
	Pitfall traps	X	X	X
	Light traps	X	X	X
	Sticky traps		X	X
	Water traps			X

In order to perform an in-depth analysis of the practical uses of monitoring methods, we asked each participant to put in practice one or several of these methods during the following growing season. Feedbacks were obtained during the second round of workshops. We observed that the monitoring methods were used in many ways:

1) Delegation of monitoring methods to the research team of the project. It is especially the case for the ones requiring specific material (eggs predation cards)
2) Use of monitoring methods with regular records according to a protocol provided by the research team of the project or extension services (beating, counting earwigs in cardboard band traps, visual soil observation)
3) Use of monitoring methods with regular records according to a protocol defined by the participant himself (visual observation of fauna and flora)
4) Use of monitoring method without record due to lack of time, because participants have no material for making record when they are in the orchard or because they are uncomfortable with the idea of writing notes (visual observation of fauna and flora, earthworm counting)
5) Use of monitoring methods to observe pest presence in place of beneficial insects (visual observation of fauna and flora, traps)
6) No use of monitoring methods to "let nature takes its course"

Beyond the diversity of uses of monitoring methods, some participants also pointed out difficulties to carry them out. First, they noticed that climate hazards impacted the establishment of beneficial insects and their monitoring process (*« the weather matters a lot. Not only the weather when you beat but also how the weather is just before. […] The temperature also matters a lot. »* Swedish workshop, March 16, 2017). Then, the participants explained that they often lacked time to use the monitoring methods that had to be implemented in a seasonal peak of workload. Consequently, they used them irregularly, when they had extra-time or even after what they considered as their normal workday (*« in the end it became something that we did in the evening from 9 PM to 10 PM. Well, it was the time when we had the time to do it. »* Danish workshop, March 21, 2017). Other participants, who decided to delegate the use of monitoring methods to workers, realized that the results of the observations were often unsatisfactory because the instructions were not clear enough. Finally, several participants reported difficulties to identify the observed insects (*"we see a lot of things but we are not so good at recognizing them."* French workshop, January 30, 2017) and to recognize their different life stages.

3.3. Monitoring programs adapted to functional biodiversity attitudes

Based on these results, we aimed to discuss monitoring programs adapted to the diversity of objectives and uses of monitoring methods, which also consider the previously described hurdles.

In our previous studies (Penvern et al., 2019), we have already identified three different approaches implemented by farmers and advisors to favour functional biodiversity. The identified approaches were "passive", "active" and "integrated". On the basis of the French semi-structured interviews and the feedbacks provided by the workshops participants, we identified four main attitudes referring to a

combination of perceptions and modes of management of functional biodiversity:

- the "wait-and-see 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 judged not 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 functional biodiversity to regulate specific pests in combination with other methods of plant protection,
- the "multifunctional attitude" based on the use of functional biodiversity to regulate pests at the farming system scale and also to reach other objectives (such as aesthetic and diversification etc.…).

These attitudes do not correspond to a single person profile. One person can indeed adopt different attitudes in regard to different biodiversity components or in regard to the different techniques they implement. Attitudes may also vary over time: for example, a farmer can have a naturalist attitude in regard to his/her hedges for some time and afterwards adopt a multifunctional attitude, based on the decision to plant fruit trees within the hedgerow. These variations may depend on the individual learning about functional biodiversity, but also on the development of general knowledge about functional biodiversity and the accessibility to monitoring methods. For example, the wait-and-see attitude can be conditioned by the fact that our current knowledge on the link between biodiversity and ecosystem services (such as pest regulation) at field scale is still incomplete. We assume that progress in the attained knowledge about functional biodiversity may contribute to increase the adoption of more proactive regulation attitudes. The variations in the attitude over time can also depend on the evolution of the farmer's experience, pest pressure, objectives of farm management, among others.

These four attitudes were presented and discussed between the participants of the second round of workshops organized in the three countries (France, Denmark and Sweden), who were asked to design

Table 3
Monitoring programs adapted to attitudes towards functional biodiversity.

	Wait-and-see attitude	Naturalist attitude	Regulation attitude	Multifunctional attitude
What monitoring methods would you recommend?	Someone adopting a wait-and-see attitude should be aware about the existence of functional biodiversity but monitors and records pests instead of beneficial insects. He/she would *"not do anything to enhance natural enemies"* (Swedish workshop, March 16, 2017) and would not use functional biodiversity monitoring methods. To favour the use of monitoring methods, it would be necessary to offer a training on insect identification and then invite the participants to make 2 or 3 observations without record, for example visual observation of aphids.	Someone adopting a naturalist approach *"would not monitor very much and would not use specific monitoring methods"* (Danish workshop, March 21, 2017). A biodiversity census in the farmer's orchard with regular observation of a biodiversity component or a specific animal or plant he/she is interested in to finally ask him/her to look at the regulation phenomenon. The pleasure would be the main motivation to use monitoring methods. *"If a farmer 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"* (French workshop, January 30, 2017).	Predation cards, observation of beneficial insects or birds to determine when to spray, observation of pest/beneficial insects or birds. *"Monitoring would be structured and systematic"* (Danish workshop, March 21, 2017).	The multifunctional approach would suppose a *"global vision"* of functional biodiversity (French workshop, January 30, 2017). Visual assessment. The use of monitoring methods would not be systematic because *"the farmer has faith in the functions of the system"* (Danish workshop, March 21, 2017) Monitoring methods should 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?	No answer	Regularly but it would be important to start the census with a training to understand how to carry it out.	It would be important to start at the beginning of the growing season. Observation linked to pests and beneficial insects' life stages. Regularly and over several years to be able to build thresholds after a while. Those thresholds would be specific to each orchard and farmer.	As much as possible during the year.
Who would use the monitoring methods?	No answer	The farmers.	The farmers or workers in charge of spraying interventions or advisors.	The farmers or a research team: *"Someone working with a multifunctional approach can/should attract lots of researchers and students who can do the observations on his/her orchard"* (French workshop, January 30, 2017).
What kind of record?	No answer	Pictures, no structured record.	Record adapted to field needs and to memorize the observations to establish thresholds.	Record for several beneficial insects and biodiversity components. Importance of a record for several years, an "historical" record.
What knowledge/ tools are missing?	No answer	Knowledge about how to organize the observation: different persons (farmer and workers, or different farmers working on several orchards) could be in charge of the observation of different biodiversity component and then they pool their observations to get a global vision of the functional biodiversity in the orchard.	No answer	One person cannot get all the skills to monitor all the produced services, the farmer should be able to find the resource-persons useful to help them to observe the different produced services.

monitoring programs (i.e. practical combinations of monitoring methods and schedules) to be adapted to the attitudes. Our objective was to determine for each attitude which monitoring method would be recommended, at what time, and at which frequency, by whom (the farmer, a worker, an advisor), with what kind of record and what knowledge or tools were eventually missing (Table 3).

The discussions during the workshop about the different attitudes validated the fact that there is a gradient of involvement in the monitoring processes in terms of knowledge, time, number of tasks and whether we can adapt monitoring programs according to the different existing attitudes and gradient of involvement. Then, it appears that asking the list of questions about monitoring programs management (column 1 Table 3) for each of the four attitudes (line 1 Table 3) can constitute a guiding framework to adapt monitoring programs for different farming situations.

4. Discussion

Previous studies pointed out the necessity to take into account stakeholder's perceptions, valuations, as well as uses of ecosystem services to facilitate their management (Asah et al., 2014; Iniesta-Arandia et al., 2014). In this article, we developed a practical approach of this topic in the field of biodiversity management and our results have several consequences concerning the development and use of monitoring methods.

Our set of inquiries about functional biodiversity perceptions broadened our understandings of what is functional biodiversity for advisors and farmers. As already observed for the notion of "biodiversity" (Noe et al., 2005; Herzog et al., 2012; Kelemen et al., 2013), there are different perceptions of what functional biodiversity is. As in the study by Lewan and Söderqvist (2002), about the recognition of ecosystem services by the general public, we assume that the different perceptions of functional biodiversity can be explained by the different levels of knowledge of participants on the notion, but also by their different visions of farm management, which can be based on more or less adaptive strategies. Therefore, it appears that if we intend to produce monitoring programs in line with farmers and advisors' ideas and needs, we cannot simply consider pest regulation services of functional biodiversity. We have to adopt more holistic approaches to consider other functional biodiversity services and uses.

Our results about the use and objectives of monitoring methods pointed out the necessity to maintain the regular use of monitoring methods in order to smooth the impact of outlier observations as well as to obtain experience with methods and the organisms of the agroecosystem. They also revealed the importance to show concrete benefits of the monitoring tools to farmers since monitoring is an additional work for them. They also showed how important is to determine who will conduct the monitoring operations while ensuring that the person receives sufficient training to carry them out adequately. These results also suggest that the delegation of monitoring operations to private or state specialized organizations could be a mean to develop them.

Last but not least, our suggestion of a guiding framework based on a combination between the four attitudes and a list of questions concerning monitoring programs management adapted to each attitude, can constitute a practical tool for advisors and farmers. For example, after a detailed presentation of the different attitudes, an advisor can ask farmers to choose different places of their farm (e.g. a plot, a hedge, a pond etc.) and work with them on monitoring programs adapted to their attitudes for each specific place. Accordingly, the guiding framework can be adapted to several uses. First, it can be used to facilitate the implementation by farmers of monitoring operations in order to adapt them to different parts and agroecological infrastructures of the farm (e.g. plots, hedges, insect shelters etc.). For example, while a regulation attitude on the row of fruit trees can require a detailed record of observations, a wait-and-see or naturalist attitude, less time-consuming and easier to implement, can be recommended for the adjacent hedge. Second, using the guiding framework in order to adapt monitoring programs to the different existing attitudes could be useful to convince some people to test monitoring methods. Third, as the different attitudes revealed a gradient of involvement in the monitoring process, the identification of the different attitudes can be used to progressively help the farmers to increase their involvement in monitoring beneficial insects. The use of the guiding framework should be then repeated over time.

If our study focuses only on apple orchards, we can imagine that our results can be extrapolated to other agroecosystems, and especially to other fruit orchards. However, a further development of this work would be interesting to confirm if the perceptions on functional biodiversity and therefore the proposed monitoring programs for other farming systems are quite similar or on the contrary very divergent.

5. Conclusion

The aim of our study was to encourage an improvement of functional biodiversity management by developing monitoring programs adapted to a diversity of perceptions and pre-existing uses by stakeholders. Based on a combination of several qualitative methods, we characterized the diversity of perceptions of functional biodiversity. A plurality of objectives and uses of monitoring methods for functional biodiversity were found, as well as difficulties in their implementation. We distinguished four different attitudes towards functional biodiversity and we developed a guiding framework to adapt specific monitoring programs to each attitude.

Our results show that it is possible to take into consideration the diversity of perceptions and uses by different stakeholders in the design of agricultural decision support tools in the field of biodiversity management. Results also suggest that by considering the plurality of perceptions and uses, a wider number of stakeholders may be involved in the process. This is essential in order to facilitate the adoption of functional biodiversity as a way to reduce the use of pesticides at a wider scale but also more broadly to reconcile agriculture and biodiversity.

CRediT authorship contribution statement

Aurélie Cardona: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Funding acquisition. **Marc Tchamitchian:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Servane Penvern:** Conceptualization, Methodology, Investigation, Writing - review & editing, Funding acquisition. **Arnauwd Dufils:** Methodology, Investigation, Funding acquisition. **Stine Kramer Jacobsen:** Validation, Investigation, Writing - review & editing, Funding acquisition. **Maren Korsgaard:** Validation, Investigation, Funding acquisition. **Mario Porcel:** Investigation, Writing - review & editing, Visualization, Funding acquisition. **Weronika Świergiel:** Validation, Investigation, Writing - review & editing, Funding acquisition. **Marco Tasin:** Validation, Investigation, Writing - review & editing, Visualization, Funding acquisition. **François Warlop:** Investigation, Writing - review & editing, Funding acquisition. **Lene Sigsgaard:** Validation, Investigation, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendices

Appendix A: Semi-structured interview guide for advisors

GUIDE D'ENTRETIEN CONSEILLERS

- Profil et activité du conseiller:

Nom du conseiller et de la structure:
Structure:

o Public
o Privée indépendante
o Au service d'un groupement de producteurs
o coopérative
o entreprise d'agrofourniture

Quel type de service fournissez-vous ?

o Conseil individuel
o Conseil collectif
o Suivi de culture
o Expérimentation
o Organisation de formations
o Autre :

Combien de producteurs conseillez-vous ? (environ)
Quel pourcentage de votre temps de travail est consacré à l'agriculture biologique ?
Avec quelles espèces fruitières travaillez majoritairement ?
Pouvez-vous décrire votre métier actuel ? Depuis combien de temps exercez-vous ce métier ?Avez-vous occupé d'autres postes avant ? Si oui lesquels ?

- Pratiques et aménagements pour la biodiversité fonctionnelle :

Qu'évoque pour vous la notion de biodiversité fonctionnelle ?
De façon générale, que pensez-vous/quel est votre avis sur la biodiversité fonctionnelle (comme levier pour l'arboriculture) ?
Avez-vous été formé à la biodiversité fonctionnelle ? (services rendus à l'agriculture, reconnaissance et biologie des auxiliaires, pratiques et infrastructures pour la favoriser etc…) Si oui dans quel cadre ? Combien de temps ?

o Quelles aménagements et pratiques (=techniques) sont généralement développés par les agriculteurs de votre secteur ? Pour quelles raisons ?
o Vos préconisations :

A présent, nous allons nous intéresser aux recommandations que vous réalisez dans le cadre de votre travail. En-dehors des techniques largement développées que vous venez d'évoquer, pouvez-vous me citer 3 techniques que vous préconisez, de la plus répandue à la moins courante

Puis pour chacune, demander de préciser :

1. Description de la technique
2. Pour quelles raisons vous la préconisez /qu'est-ce qui vous a convaincu (ont-ils d'autres critères d'évaluation que l'efficacité ou l'opérationnalité, autres intérêts) ?
3. D'où vous la connaissez (issues de la recherche, de l'expé – doc technique – ou vu chez d'autres agriculteurs) et depuis quand ?
4. Les agriculteurs auxquels vous la conseillez (et sous quelles conditions ?) ? (cf agriculteurs expérimentés ou non, innovants, convaincus vs sceptiques…)
5. Si elle est facilement adoptée ? et sinon quels sont les freins ? (Manque de connaissance et de savoir-faire ? Manque d'efficacité ou bénéfices invisibles ? Pas opérationnelles face aux contraintes technico-économiques « verrous techniques »)

Comment présentez-vous ces pratiques aux agriculteurs (ont-ils des exemples de doc technique à fournir) ?
Il y a-t-il d'autres techniques dont vous avez entendu parler et que vous ne préconisez pas ? Pourquoi ? (+ méthodes dont il sait que ça ne marche pas)
Parmi toutes les techniques que vous connaissez, pouvez-vous me citer la plus efficace selon vous ? La plus facile à mettre en place ?
La plus originale ?
Concernant toutes les techniques de biodiversité fonctionnelle dont vous venez de parler, voyez-vous d'autres intérêts à ces techniques que la régulation des ravageurs ?

o Agriculteurs à interroger :

Certains agriculteurs sont-ils plus réticents que d'autres à l'adoption de ces techniques ? Si oui
pourquoi ? (sceptique, manque d'expérience ?, « verrous humains »)
Pouvez-vous me donner les coordonnées d'arboriculteurs à contacter dans ce domaine ?
Sceptiques et convaincus ? Expérimentés ou non ? Mettant en œuvre (ou ayant mis en œuvre et
abandonné)

- Méthodes d'évaluation de la biodiversité fonctionnelle :

Comment évaluez-vous les effets de la biodiversité fonctionnelle ?
Décrire la méthodologie associée (objectif, matériel nécessaire, fréquence, échantillonnage, indicateur/ unité de mesure, bio-agresseur visé et.) et un éventuel lien internet de référence ou document technique.
Etes-vous familier avec les méthodes de suivi de la biodiversité fonctionnelle ? Oui/Non
Dans le cadre de votre activité, utilisez-vous les méthodes suivantes pour suivre la biodiversité fonctionnelle (pour chaque méthode, description de l'utilisation, de son efficacité) :
Le battage

o Le comptage visuel
o L'évaluation des dégâts
o L'évaluation du rendement
- Evaluation des méthodes

Parmi les méthodes d'évaluation de la biodiversité fonctionnelle que vous pratiquez et connaissez, lesquelles vous semblent directement utilisables par les producteurs ? Pour quelles raisons ?

- Perspectives :

Comment votre structure considère la biodiversité fonctionnelle ?

Dans le contexte actuel de réduction des pesticides (Plan Ecophyto etc.) :

Considérez-vous la biodiversité fonctionnelle comme un levier d'avenir pour la gestion des ravageurs ?

Quelles propositions feriez-vous ?

Appendix B: Semi-structured interview guide for farmers

GUIDE D'ENTRETIEN AGRICULTEURS

- Profil du producteur et de l'exploitation

Pouvez-vous décrire brièvement votre exploitation?

(Superficie, nombre de salariés, part de l'arboriculture, certification AB ou autre, part de la pomme, système

de commercialisation…)

Pouvez-vous décrire l'historique de votre installation ?

(formation, expérience, reprise ou installation de novo…)

Etes-vous suivi techniquement ? Si oui comment ? A quelle fréquence ?

Selon-vous, quel est le rôle d'un bon conseiller agricole ?/qu'attendez-vous d'un conseiller agricole ?

Pouvez-vous décrire vos parcelles en pommier ainsi que la conduite du verger que vous menez ?

Taille, âge et nombres de parcelles, densité de plantation, type de variétés, conduite de l'arbre, irrigation, entretien du sol, désherbage, fertilisation, rendement moyen…

Gérez-vous vos parcelles différemment les unes des autres ?

Quels sont les principaux problèmes phytosanitaires auxquels vous êtes confrontés ? Quelles méthodes de protection utilisez-vous contre ces principaux problèmes?

- Pratiques et aménagements pour la biodiversité fonctionnelle

Qu'évoque pour vous la notion de biodiversité fonctionnelle ? Qu'en pensez-vous ?

Avez-vous été formé à la biodiversité fonctionnelle ? Si oui dans quel cadre ? Combien de temps ?

Est-ce que vous cherchez à favoriser la biodiversité fonctionnelle dans vos vergers ? Quels aménagements et pratiques ? Depuis quand ?

Qu'est-ce qui vous a amené à les mettre en place ? D'où connaissez-vous ces techniques ?

(Echange entre producteurs, rôle du conseiller etc…)

o Enherbement

Pouvez-vous décrire votre méthode de gestion de l'enherbement ?

Rang/interrang, semis ou non, fréquence de tonte/fauche, matériel etc…

Pour quelles raisons le gérez-vous ainsi ? Quelles sont les limites ?

Multifonctionnalité, intégration dans le système de culture…

o Gestion des haies

Pouvez-vous décrire le linéaire de haie présent sur votre exploitation ?

Longueur de haie, type de haies, largeur…

Quel entretien en faites-vous ?

Quels en sont les avantages ? Les limites ?

o Gestion des produits phytosanitaires

Comment raisonnez-vous l'application des produits phytosanitaires dans vos vergers ?

Pour quelles raisons ? Quelles difficultés rencontrez-vous ?

o Autres méthodes

Bandes fleuries (localisation, quel mélange, quel entretien, quelle fréquence de renouvellement, avantages et limites ?)

Nichoirs, gîtes et perchoirs (quel type, densité à l'ha, quel entretien, avantages et limites ?)

Il y a-t-il des techniques que vous avez mises en place un temps puis abandonnées ? Si oui lesquelles et pourquoi ?

Il y a-t-il d'autres techniques que vous connaissez (vu ou entendu parler) mais que vous n'appliquez pas dans vos vergers ? Si oui pourquoi ?

o Parmi toutes les techniques que nous venons d'évoquer et peut-être d'autres qui vous viennent en tête, pouvez-vous me citez laquelle est selon vous :

- La plus facile à mettre en œuvre
- La plus efficace
- La plus originale

Et m'expliquer à chaque fois pourquoi ?

o Concernant toutes les techniques dont vous venez de parler, leur trouvez-vous d'autres intérêts que la régulation des ravageurs ?

Chercher à percevoir laquelle est la plus aboutie ou adaptée pour la mise en place d'une méthode de suivi.

- Méthodes de suivi

Comment évaluez-vous les effets de la biodiversité fonctionnelle ? (diminuer pesticides, biodiversité au sens large etc.)

Connaissez/pratiquez-vous des méthodes de suivi de la biodiversité fonctionnelle ? Sont-elles utilisables directement par les producteurs ? Pour quelles raisons ?

Vous paraît-il important qu'un producteur suive lui-même la biodiversité fonctionnelle présente dans son verger ?

Sinon qui ?

Seriez-vous intéressés par tester une ou deux méthodes de suivi de la biodiversité fonctionnelle ?

- Perspectives

Dans le contexte actuel de réduction des pesticides (Plan Ecophyto etc.) :

Considérez-vous la biodiversité fonctionnelle comme un levier d'avenir pour la gestion des ravageurs ?

Quelles autres propositions feriez-vous ?

Quelle évolution a connu le secteur de l'arboriculture ces dernières années ?

(Principaux changements, quelles difficultés, quelles perspectives pour l'avenir…)

- Contacts

Connaissez-vous d'autres arboriculteurs que je pourrais interroger sur ces questions ? Qu'ils soient expérimentés ou on, sceptiques ou convaincus ? Dans le secteur proche ?

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