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Co-design methodology. Design process of an innovative experimental orchard in Southern France, Drôme

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M.Sc. Agroecology

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Abstract:

Fruit production is among the crops using the most pesticides, affecting both the quality of the environment and human health. In this context, the INRA Gotheron experimental station (Drôme, France) leads a project to test an innovative low-input orchard to be managed without any pesticide (even organic) to foster ecosystem services, especially pest suppression. To overcome the lack of hindsight and experiences on innovative perennial agroecosystems, the expertise of stakeholders from diverse occupational categories was mobilised in a workshop divided into four sessions. Their analysis aimed to understand how ideas were constructed during the work sessions and how the workshop output could be reused to design a prototype to be planted. Firstly, prototypes differed in general design and components proposed. Secondly, exchanges more than outputs were source of interest for participants. Surprisingly, there was flexibility among participants’ roles, especially concerning facilitation. In addition, the spatial layout used in the session was important as an intermediary object, to refocus participants on the discussion. Lastly, the ideas proposed during the workshop, were either adopted, transformed (evolved proposals), bypassed (alternative proposals), or merely rejected. This work opens doors for further research on agroecological design, fields of expertise to gather into co-design workshops, animation technics and finally the production of new knowledge thanks to collective knowledge sharing.

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Illustrations and tables

1. Introduction

Intensive agriculture rose after World War II. To feed people, increased animal and plant production were necessary. **Industrialization and globalization** helped to build agricultural models where production factors were better controlled (Lauri et al, 2016). Therefore, **productivity** became the main objective regardless of the cost of any other. **Specialization** of agricultural products led to models such as straight designed monoclonal orchards (‘set of linear monocultures of clonal (cultivar) and perenial crops’) (Simon et al, 2011). On an ecological point of view, those systems are extremely **simplified** so that human labor is minimized and simplified too. However, they use high **chemical inputs** to fertilize and control pests, which have implications on the environment, human health and global agricultural system health on the long term (e.g. soil erosion, organic matter and functional biodiversity losses) (Aubertot et al, 2005).

Organic agriculture principles are primarily based on **ecological principles** (IFOAM, 2014). However, increasing market demand (where 78% of organic products bought are fruits and vegetables, Agence Bio, 2015) led some producers to be confronted with the same constraints and bottlenecks as conventional producers. As a result, organic agriculture is not always a sustainable agriculture if the primary interests are attractive prices (higher prices for producers, lower prices for customers). Low cost organic agriculture is rather similar to intensive agriculture with basic substitution of chemical inputs by organic-registered ones. It may be harmful to the environment since regulations permit the use of unselective pesticides, e.g. copper or spinosad (Simon et al, 2011).

The control of production factors and the simplification of the agroecosystem developed a mindset among producers of **minimizing risks**, opposed to a **management of incertitude factors** (Toffolini et al, 2016). As a matter of fact, a **vicious circle** begins with the loss of functions of the agroecosystem through the use of pesticides, that disrupts ecological services (e.g., pest suppression) and/or leaves free ‘niches’ (i.e. the position or function of an organism in a community of plants and animals) for the development of induced pests that in turn require more pesticide use. Finding more drastic solutions to control pests would enhance this vicious circle, whereas there is an obvious **need to change the system** (Meynard et al, 2012). To reverse the circle, the new system should include pollution and climate change issues, integrating soil fertility, natural enemies and pollinators’ conservation (e.g., through provision of habitats and resources) as well as genetic diversity in the design process. Several publications refer to ecological principle reliance (Debaeke et al, 2009; Malézieux, 2012) although others refer to agroecology (Berthet et al, 2015; Simon et al, 2017; Deguine et al, 2016). This new way of thinking matches societal demand for safer products and environment.

Some motors may activate this agroecological transition while others would exacerbate the lock-in effects of the current system.

Globalization may help because it allows scientific resources to be shared via internet, e.g. webofknowledge.com, researchgate.net and local success stories such as ‘La Via Campesina’ (Desmarais, 2012). It would help to create a ‘collective intelligence’ about general principles, even if a case study is by definition a ‘real-life events’ analysis that should not be adaptable to other locations, especially when studying a given ecosystem’s particularities. However, depending on case studies, it is possible to “arrive at broad generalizations based on case study evidence but without presenting any of the individual case studies separately” (Yin R., 2009, ch.1, p.20)

In France, the ‘Ecophyto’ plan aiming to reduce the use of pesticides (Laget et al, 2015) and the ‘transition agroécologique’ plan led by the French Ministry of Agriculture (Bidaud F., 2013) helps to fund research on agroecological principles and favor the set-up of farms using them. It gives credibility as well to agroecology regarding society, coupled with an increasing demand for organic products (Agencebio, 2015).

However, changing the system is not that easy since lock-in effects slow down food supply transition (Meynard et al, 2012). Both consumers’ choices and food supply intermediaries drive fruit **standardization** resulting in fruit wastes as well as losses of genetic resources (Lieblein et al, 2001). Indeed, market rules imply that producers are in fact not totally free to choose their cultivars, fruit standards and prices. This promotes intensive systems in which a high productivity is the easiest way to generate income.

Another lock-in effect concerns **research**, firstly because of a lack of scientific knowledge and tools to design and manage complex systems, which are subject to numerous uncertainties. This implies crossing several dimensions, disciplines, scientific and empiric knowledge from local stakeholders (e.g. producers, advisors) (Berthet et al, 2015; Rickerl and Francis, 2004).

In addition, **top-down research** is now controverted, since it can be highly disconnected from real producers’ needs; a disconnection explained on several levels in the socio-technical system from a research result to its possible field application and adoption (Le Gal et al, 2011).

The new paradigm imposed by the development of agroecology also implies a new understanding of innovation processes, with attention paid to their grounding in local situations. In the field of agricultural science, the idea that scientific knowledge may be assumed to be universal across local situations has been questioned. A relocalisation (Warner, 2008) of knowledge production is needed. Moreover, agroecology requires the use of systems approaches to address complexity up to the ecosystem level (Vanloqueren and Baret 2009). It therefore requires mobilizing stakeholders with multiple perspectives and crossing scientific with empiric knowledge.

Agroecological innovation thus depends both on changes in the integration of knowledge about ecosystem regulations and agricultural technologies; and on changes in the social interactions inherent in knowledge production.

Researchers at several experimental sites including the INRA Gotheron station (INRA-PACA, Drôme, France) have worked for over 20 years on the design, management and multicriteria evaluation of innovative orchards towards more sustainability. The station is situated in the Rhône valley, on a traditional tree production plateau, mainly apple, walnut, peach and apricot. The climate is between continental and Mediterranean. Lands are mainly alluvial with clayey-sand soils. These two factors explain the suitability for growing perennial crops and therefore the pressure of pests, especially, the two challenging pests for apple tree production - the coddling moth *Cydia pomonella* and the apple scab *Venturia inaequalis*. Indeed, according to Gotheron experimentations (Simon et al, 2011), losses due to these two pests could reach up to 80 to 100% of production. This also explains the intensive use of pesticides in this region.

A previous experiment by Gotheron, **BioREco** (2005-2015), aimed to reduce pesticide use in apple orchards. The results of this system experiment showed that such reduction was to some extent possible when combining low-susceptibility cultivars, a range of methods alternative to chemicals and an acute evaluation of damage risk due to pests. Most of the levers of action (i.e. concrete controlling means) in that project targeted the pests either directly or indirectly through cultivar choice and tree training. In the most integrated systems, pesticide use was reduced by 45-56% compared to the regional reference. Such reduction was achieved with similar yield levels, but further pesticide use reduction could hardly be possible without fruit loss due to pests in the experimented orchards (Simon et al, 2011). This work outlined the necessity to deeply redesign the orchard system to get away from dependency on chemicals to produce fruits. Indeed, Hill and MacRae (1996) published "conceptual framework for the transition from conventional to sustainable agriculture". They divided sustainable transition into three progressive categories: **efficiency, substitution and redesign**. Efficiency strategy targets the same productivity objectives with reduced energetic or human costs (e.g. IPM, i.e. Integrated Pest Management, efficient control). Substitution includes alternatives measures that avoid chemicals or nonrenewable resources (e.g. solar energy, biocontrol). Redesign, in contrast, questions the entire system (e.g. permaculture, agroecology): the objectives, the study framework, the resources used, the integration of food system stakeholders and the way to evaluate such new systems. However, according to Hill and MacRae (1996) re-design strategy is rarely applied if institutions didn't first try efficiency or substitution strategies. BioREco project used both efficiency and substitution levers. They concluded that maximizing ecosystem services requires deep redesign to free the fruit tree agrosystem from pesticides sustainably.

Based on this need for innovation, the same team working on BioREco started a new project in 2015 called **'Z project'** that aims to create a fruit tree-based system in a pesticide-free multi-species, multi-layers and multi-service agroecosystem. Ecosystem services would be at the core of the system re-design, targeting first pest regulation by natural enemies, soil fertility upkeep, pollination and the production of fruit and others cultures.

Usually, ecosystem services are studied separately, but farmers depend on several ecosystem services related to pest suppression, pollination, soil fertility or/and production. Lescourret et al (2015) proposed a general framework to manage multiple ecosystem services in a socio-ecological approach but the authors haven't experimented this approach yet.

The Z project aims at just such general approach and is three-dimensional: the **spatial scale** is defined to englobe the plots (supra-plot), which means that the study would integrate the plots, the farm scale (seen as a part of the experimental unit) as well as the territory/landscape; the **temporal scale** is planned on the long term, over 15 years, which allows production complementarity; the third scale is the integration of the

fruit sector with food processing and commercialization issues (diversified distribution network, restricted fruit standardization and territorial complementarity).

Therefore, the Z project scales up the study limits to involve other stakeholders within the fruit sector, including farmers, agronomists, researchers and food system intermediaries. The approach aims to be **collective** with increased interaction and partnerships among various actors. In addition, the project is **multi-disciplinary** (agronomy, ecology, pathology, entomology, soil science, economics and social sciences), and requires knowledge and skills from different backgrounds. Finally, the project has a **pedagogic** dimension, targeting agricultural training and higher education, to exchange and produce knowledge in direct interaction with trainees.

Naturally, next comes the question: **how to design such an agroecological system?**

Gotheron's team wishes to gather all knowledge and expertise available to have both **holistic and embedded** agro-ecosystems, integrating ecological principles, agronomical consistency and feasibility. They decided (supported by Ecodéveloppement department, INRA Avignon) to use, **eco-design** and **co-design** methodologies. Co-design is associated with participatory science since skills and expertise are owned by multiple stakeholders of the food system (Penvern et al, 2014; Berthet et al, 2015).

Eco-design aims to define the properties of sustainable orchard properties and the identification of ecosystem functions likely to increase ecosystem services, e.g. pest suppression, pollination, soil fertility (Simon et al, 2017).

Indeed, we need both eco-design and co-design to exchange implicit and explicit knowledge on agroecological science and practices, to foster agroecological processes and reach sustainable orchard property. (Penvern et al., 2012). That is where the two INRA stations decided to organize a workshop based on expertise to help the design of the Gotheron module with *de novo* co-design methods.

Whereas publications often report *step by step* design processes, i.e. with iterative loops of improvements once solutions are tested by farmers, Gotheron, in this case, wanted to design an experiment to be implemented over a 15-year period. That is called *de novo* design in the literature (Lauri et al (ed), p.93, 2014). To be more precise, the design process is called 'prototyping' in the *de novo* design methodology and each theoretical version of an orchard is called '**prototype**'. The team of Gotheron is thereby both the beneficiary and manager of the project.

Research in ergonomics, e.g. Barcellini et al. (2015), have investigated collaborative design activities occurring in design meetings to analyze the epistemic content of the design interactions between participants. This socio-cognitive approach reveals how the negotiation of various perspectives contributes to building design solutions.

My internship started mid-January partly to meet the previous trainee who worked on the identification of the possible levers to design the prototype. My work was therefore two-fold: i) to observe the global process of prototyping at Gotheron: a progress from pre-prototypes to a final prototype ready to be experimented (in late 2017). The idea is to consider components implemented into the system regarding **overall**

consistency, feasibility and applicability. This requires deeply considering trade-offs that would have to be made to move from an abstract to a concrete prototype, and ii) to analyze a co-design workshop process to understand what influences outputs of workshops.

This case study should help to conceptualize and propose **methodological learnings** for further modules to be developed and experimented in the project, as well as for broader purposes than Gotheron case study, about *de novo* agroecological co-design, and particularly knowledge sharing and elicitation, skills and expertise gathered and the methods to combine them, required to produce finalized prototypes.

There are therefore two main hypotheses considered in my internship:

- Concerning Gotheron's final prototype elaboration: if we replace the use of inputs by a system redesign that maximises ecosystemic services, then we would have a sustainable orchard.
- Concerning the workshops: If the workshop proposed in the design process fits Gotheron's objectives, i.e. to maximize the stakeholders' creativity and fill the gap of knowledge to transform pre-prototypes based on the literature into prototypes ready for experiment, then we will be able to repeat the experience for other systems in the 8-hectare experimental area and propose an experimental framework for other *de novo* agroecological design.

2. Material and Methods

2.1. Case study description and workshop organization

The 8-hectare area intended for the 'Z' project should be designed at the supra-plot scale with global agro-ecological infrastructures (e.g. windbreaks, pound, hotspots of biodiversity) and experiments of several units called '**modules**'. The supra plot scale allows us to have productive zones and 'production supporting' zones within and between modules. The design of the first module (about 1 ha) started two years ago with the aim of defining the objectives and general framework.

Before I started my training period, another intern had worked on the **'pre-prototypes'** design, i.e. systems described by their functional components and arrangement (layers, plant assemblages and/or individual plants that support functions providing the targeted ecosystem services) based on bibliography. The approach was **'pest suppressive'** on three problematic pests in an apple-tree based system (Rosy Apple Aphid *Dysaphis plantaginea*, Apple Scab and Codling Moth). The pre-prototypes identify different levers including dilution and barrier effect so that plants should be more difficult to localize and colonize; a focus on genetic resources using low pest susceptibility species and cultivar; and a natural enemy presence boosted by the provision of resources and habitats through agroecological landscaping. The intern finally proposed two 'pre-prototypes' (Appendix 1) because mixing pre-prototypes into one system was incompatible between disease and insects' levers, particularly the 'aeration' of the orchard for apple scab vs hedge benefits for the presence of pests' predators.

After the levers identification by the previous intern, my master thesis focused on the process of prototyping. As we can see in figure 1, this process is not completely linear, there are some loops of improvement to adapt levers when trade-offs are necessary and evaluate *a priori* the performances of the final prototype. Indeed, the Gotheron team should adapt the prototype to make the expected performances fit the objectives.

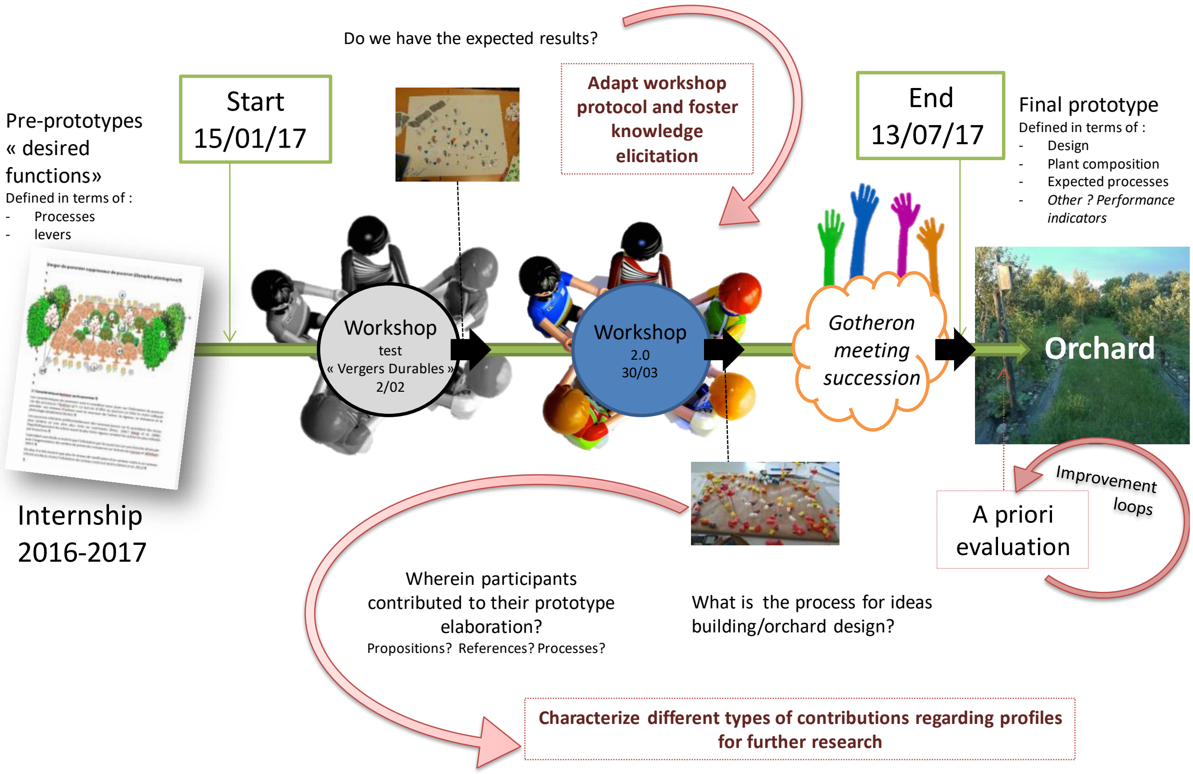


Figure 1 General design approach for module 1

2.2.1 First workshop (VD workshop)

To define the prototypes, we organized two workshops: One at the beginning of my internship (2.02.2017) and one in March (30.03.2017). We used the first one as a 'crash test' to test the method for the second one, since we knew the first workshop would not be as prepared as the second one. The second reason was that most of the participants of the first workshop were familiar with workshops. Indeed, the 'Verger Durable' group is a European group of researchers, advisors and fruit tree farmers that gather every year to exchange knowledge on orchards management, agroecosystem understanding, and visit innovative orchards (Penvern, 2013). This first workshop referred to as Verger Durable workshop (or VD workshop) was the perfect ground to test our methods, e.g. information given before the design session, starting the work session from a pre-prototype, animation methods and the supports used for design purposes (paper boards and stickers), for the second workshop (referred as workshop 2.0). After VD workshop, we analyzed if we had the results we expected and what could be learned from it. What could we change in the organization and animation of workshop 2.0 to maximize participants' contribution, their capacity to think 'out of the box', i.e. referring to their creative capacities, and get a finalized prototype regarding Gotheron objectives?

Our approach for the VD workshop was to present them with the Z project firstly (Gotheron context and objectives) followed by the presentation of the 2 pre-prototypes from the previous internship.

For the VD work session, we set-up two tables with 6 participants on each (9 with animators). We mixed stakeholders (numerous researchers) by professional activities, e.g. researchers, farmers and experimenters, by fields of expertise, e.g. apple scab, biodiversity, genetic resources, and participants' locations. We assigned one facilitator to oversee discussions, one key informant to explain the levers of the pre-prototypes and one observer.

We gave different directives to the two tables: one table would focus on managing apple scab (disease approach or DA) while the other (pest approach or PA) would focus upon managing Rosy Apple Aphid and Codling Moth (Appendix 2).

We learned from this workshop that the preprototype approach probably over-detailed the levers and therefore reduced the creativity of participants because no new lever was proposed. We observed that participants brought different types of contributions such as references, technical proposals (i.e. applicable ideas), or arguments. We found this would be a particularly interesting classification to better understand how an orchard is co-designed.

Our new hypotheses were therefore that professional activities may be correlated with the types of contributions, e.g. key informants give information on processes, researchers provide references, farmers propose applicable solutions. In addition, according to the experience participants have in their professional activity, it may influence the nature of their references, e.g. farmers refer to personal experience, advisors refer to observations, researchers and experimenters both refer to experiments and publications (Appendix 3).

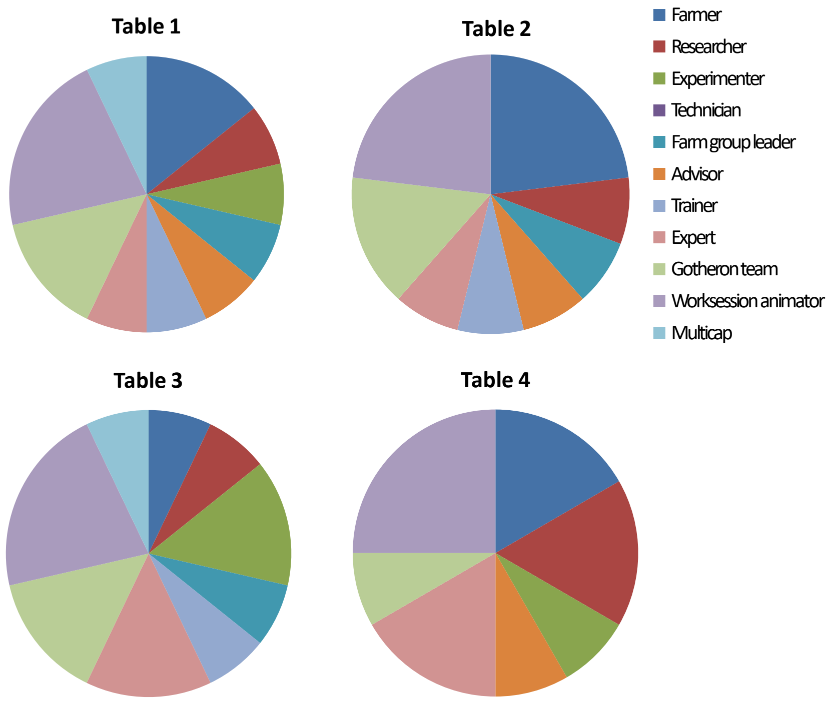
2.2.2. Second workshop (workshop 2.0): composition and program

Table composition

To compose tables, our first hypothesis regarding agroecological co-design was that mixing professional activities e.g. farmers, researchers, technicians would influence final prototype to be consistent and holistic thanks to a diversity of types (empirical or scientific, situated or generic) and nature (e.g. technical proposition, processes, arguments) of knowledge (Toffolini et al, 2016).

We invited participants according to their professional activity category, their proximity and their capacity to think out of the box. Expected categories were: farmer, researcher, experimenter, farm group leader, advisor, trainer and expert (biodiversity, pest control levers (from Gotheron), or plant associations). Since most of the invited persons agreed to participate, four tables were planed instead of three, resulting in some differences in professional categories between tables, e.g. no experimenter on table 2 (Fig. 2). Indeed, we tried to mix participants regarding their experience, their personality (we did not want a table with only strong personalities), their gender, and their knowledge of other participants.

Workshop program



The objectives of the introduction and animation of the workshop were to i) create a comfortable atmosphere to foster participation implying knowledge elicitation, ii) introduce Gotheron context and possible levers at best for their understanding without referring back to the general framework too often during the work session; and iii) to present the role of animators in order to facilitate discussion without off-topic speech. Appendix 4 shows the detailed schedule of the workshop 2.0.

Figure 2 Participants' distribution by professional activity (%)

We planned workshop 2.0 over a half day instead of a complete day, to favor producers' participation. Indeed, end March sees the beginning of high season for fruit tree producers and we thought their presence was essential for the prototypes design since they are the best spokespeople to discuss the realism of the prototype for fruit tree implementation and management, and are also possible end-users of the work.

The most unusual ways of introducing the work session were probably the plenary show of hands and the small theatre scene. we proposed several ice-breaking ideas in groups. We finally adopted a plenary session to save time. The show of hands included questions about participants' location, their motives for coming, their familiarity with innovative orchards and their vision about 'producing fruit differently'.

The small scene was a very simplified representation of the effects levers would have on pests: repulsive plants would repulse, dilution and barrier would disturb, predators would suppress, and similar species would compete for ecological 'niches'. The scene was acted out twice by the Gotheron team (including trainees): once without speaking and a second time with explanations. This aimed to disconcert and make an impression on participants for a better understanding of the possible levers. Moreover, it would put participants in a dynamic mood, changing from a classic power point presentation. The 'story' was about a pest (e.g. a rosy apple aphid) looking for its host, the apple tree (actually a blue chair) and disturbed by obstacles on its way. One member of the Gotheron team played the pest, was first stopped by a hedge-barrier (a team member) then attracted by an armchair (i.e. the trap plant) on its way to the blue chair and repelled by a smelly shoe (i.e. the repulsive plant), followed by a meeting with a predator. Finally, the pest sat on a grey chair, representing another fruit tree species, next to the blue chair, which was already occupied. The scene ended with the death of the pest after the 'attack' of a predator.

After the theatre scene, the levers were presented more classically through a slide presentation to introduce the levers they may use, in the form of a list (see appendix 5) in order not to influence the design.

Regarding the animation of the work session, we chose to have three 'neutral' animators on each table: one facilitator (external from Gotheron and sometimes from fruit tree management) was in charge of sharing speaking time, giving voice to the more discreet participants and keeping participants focused on the work session objectives; one rapporteur (familiar with Gotheron) took notes on a paper board as a list, a mind map or with 'post-it' -as we did not ask them to follow a particular format- and asked participants to clarify and precise ideas. In addition, rapporteurs oversaw intermediary syntheses to state propositions and discuss to work session progress regarding objectives. We also assigned logistic support (from Gotheron mainly) to each table. Members of the Gotheron team, key informants, were present at each table for information about the parameters of the module, and one member of Gotheron familiar with pests' regulation levers. We asked to two participants to be our 'main witnesses', after taking part at one table they exchanged restitution tables and finished the workshop with short syntheses representing their own point of view (see Appendix 6 for more details about the composition of tables and several organizations represented by participants).

After the work session itself, there were two cross-restitutions in parallel, and finally, we held a plenary discussion with participants in order to get 'hot' feedback from the work session, the workshop in general and to raise a possible agroecosystem co-design partnership.

2.2. Gathered materials

For the work session, we had different materials supporting participants to express decisions, to refer to the levers and to visualize the orchard on process: the paperboard of the rapporteur, a trestle with levers (appendix 5) and a plate of polystyrene (symbolizing the plot) on which participants could write and pick toothpicks and 'Playmaïs©' (i.e. colorful small soft cylinders made of corn for children, see appendix 7) as the discussion goes.

In addition, to get to know participants better and confront results with their feedback, we asked them to complete a questionnaire in two parts: one before the work session and one after.

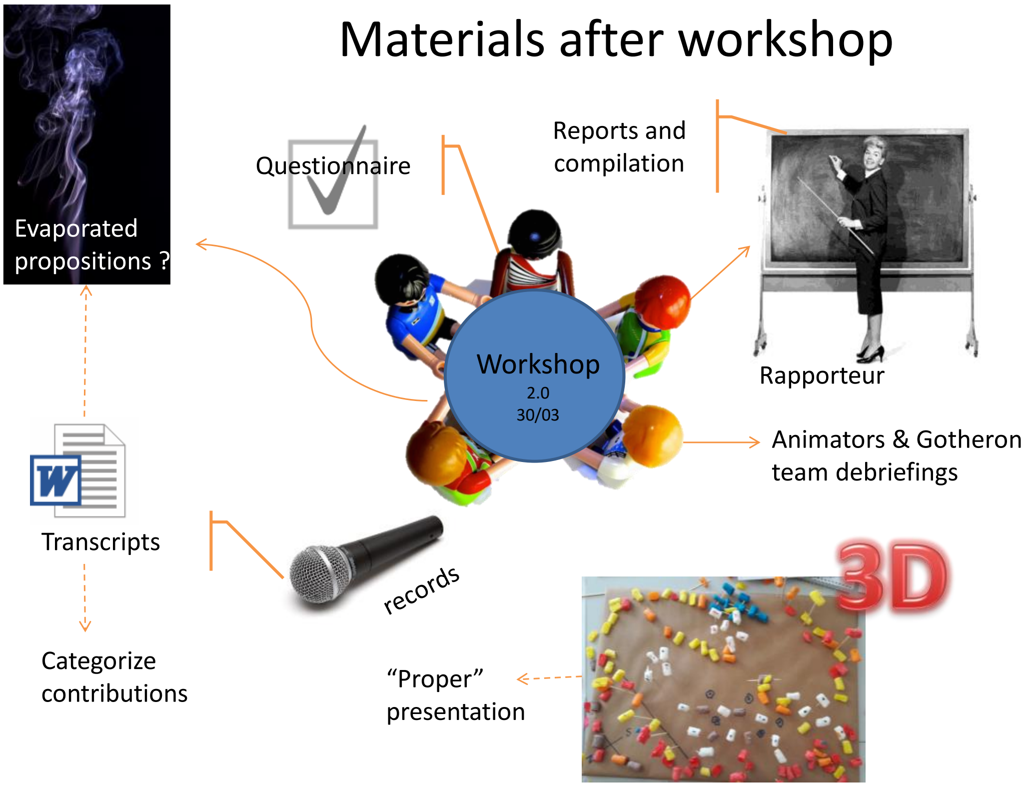


Figure 3 Materials collected during and after workshop 2.0

After the workshop, we had different types of materials collected to analyze (Figure 3): records we transcribed, questionnaires, spatial layouts made with Playmaïs© (Appendix 7) sketching the 4 prototypes referred to as 'Playmaïs layout' and rapporteurs' reports we compiled. After the workshop 2.0, we also had several levels for debriefings: facilitators-rapporteurs, observers and the Gotheron team.

2.3.1. Questionnaires

For the workshop analysis, the questionnaire (appendix 8) had both multiple choice and open questions for clarification, e.g. professional activity and experience, fields of expertise, familiarity with participatory workshops. Several questions were repetitive with the show of hands e.g. key words when thinking 'produce fruit differently', reasons for coming because the vote was very quick and not every stakeholder had time to participate. In the second part, after the work session, we wished to catch their subjective contributions ('perceived contribution'), the satisfaction or frustration about their table results, some suggestions for further workshops, a message to take home and if they were ready to come back.

2.3.2. Transcripts

Each table was voice recorded with the transcription provided afterwards. This allowed a better analysis of participants' contributions some of which were disappointing since there were some adjacent discussions or incomprehensible words. We tried to film a table but we had problems with equipment.

2.3.3. Playmaïs layouts transformed in computer representation.

One of the first tasks after the workshop, was to transform the Playmaïs layout of the 4 tables into a 'proper' presentation and complete it with the rapporteurs' reports. To draw it, we used the software 'SketchUp©'

to draw layouts and specific composition (see Figures 5,6,7 and 8 in 3.1 results). The aim was to have consistent material to support Gotheron discussions based on output from the workshops. A second aim of the SketchUp versions would be their used in a booklet intended for the participants, including a short description of the four prototypes, some data from the questionnaires and general results about participants' contributions.

Therefore, results could be divided into three levels of analysis: the upcoming series of Gotheron meetings to see how they understand and use the workshop prototype for the final Gotheron prototype; the entire workshop with questionnaires and feedback to understand stakeholders' profiles and their contribution to the co-design process for further research; and finally, on the work session, to understand how ideas are constructed and perhaps influence results.

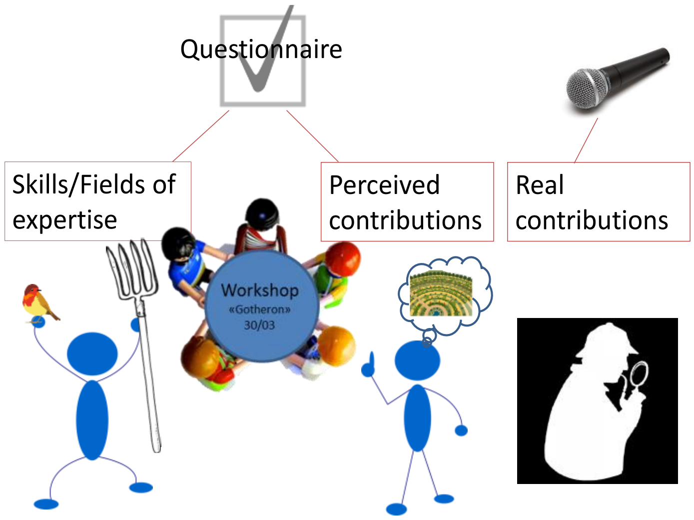
2.3. Analysis

2.3.1. Gotheron meeting succession

During this series of meetings, I was mostly in Avignon so I followed them in videoconference. I realized afterwards that it allowed me to take a step back from the process to define different steps along the process as well as team interactions. The aim of the series of meetings was firstly to debrief the workshop within the team, then to understand as much as possible about the prototypes designed during the work session thanks to the computer-based sketches of the prototypes and a compilation table from the rapporteurs' reports to retrieve justifications for the choices regarding components and design.

2.3.2. Fields of expertise and knowledge shared

The questionnaires were used to describe similarities and differences among participants concerning their professional activities, their experience, their fields of expertise, their familiarity with workshops and their perceived contributions.



The differences between actors' field of expertise (i.e. what we consider as skills) the perceived contributions (i.e. topics on what they think they contributed) raised in the questionnaire and thirdly, the real contributions, from our perspective and from the records were also considered (Fig.4). As a retrospective, we could analyze if our categories matched with their perceived contribution, and their subjective skills.

Figure 4 Different levels of stakeholders' contributions for analysis

2.3.3. Categorization of contributions

We firstly processed the contributions into a spreadsheet for each table and each participant based on the transcripts. In total, we had 2516 contributions that we categorized by types and nature of contributions.

The different types of contribution are our first level of categorization: What did the participants' aim when contributing? Did they want to propose new ideas, express decisions, raise points for attention, give strength to an idea?

The second level of categorization concerns the nature of the contributions: What are the topics discussed? Some nature of contributions are not presented here because we did not analyzed them furtherly.

Table 1 The different types and nature of contributions and the information they covered

Types of contribution	Nature of contribution
Technical proposals: the new applicable ideas	-Genetic resources: root stock, cultivar -Biodiversity: Agroecological infrastructures, companion plants -Fruit tree associations: combination with other productions, cultivar and species diversification -Orchard management, cultural practices: mechanization, management through time -Soil fertility: nitrogen management, fertilization -General spatial organization: trees access, lines or pathways -Commercialization: processing and food supply -Animal integration
Processes: how the system works, the mechanisms behind a lever or detailed and neutral explanations	
Framework: when participants question objectives of the exercise or when Gotheron team give elements of context.	
Reference: when the source of information is clearly cited.	-Personal experience or observation -Own experimentation or from other stations -Publication -General examples
Positive (or Constructive) **argument:** justification for a proposition without reference, or information on the expected effects.	
Queries: questions related to:	-Lack of knowledge -Protest -Justification -Precision
Negative argument: clear opposition	-Opposing objectives of a proposal -Referring to feasibility -Implying a disinterest of the proposal

Validation: Approbation, repetition or statements	

Compared to the questionnaire categorization of perceived contributions, we used a new and more adapted categorization more adapted (to Gotheron expectations of the Workshops) and to the proposals when analyzing transcripts. Proposals have in fact been organized in terms of levels of action and not in terms of objective as the standard today to describe agricultural fields of expertise.

To analyze the different contributions, we used several methods, i.e. tables for categorization, timelines, histograms, and 'fish' (see 2.4.4). We did descriptive statistics since our quantitative and qualitative data are represented on little samples of each professional category or field of expertise.

Finally, to analyze contributions per profile, since some professional categories were underrepresented, we grouped (see 3.2.2) experimenters with researchers and farm group leaders with animators and trainers to have more homogeneous groups in number of people, to improve visibility of histograms and because they are close enough when analyzing groups separately.

We mainly used 'Microsoft Excel©' to analyze data as well as the software 'Xmind©' to create the 'fish' (see below).

2.3.4. Timelines and fish to analyze the content of the discussion throughout the work session.

A second analysis looked at the sequence of the technical proposals appearing throughout the work session, for each table with a timeline. As we did not have the exact timing for each contribution but all tables had the same time, we carried out an approximation using the line of the contribution proportionate to the last line of the transcripts. Timelines helped us to show some tendencies regarding the order of the topics discussed.

Since the aim of the analysis was to understand better how ideas (i.e. groups of contributions on the same issue, including several technical proposals, arguments for and against them and decision-making elements namely the implementation of the idea onto the Playmaïs layout) were generated, adopted or rejected, we investigated interactions between the proposals and the other types of contributions throughout the design process. We therefore chose to represent discussions on mindmaps shaped as fish to show (i) the main ideas discussed (one idea = one fish), (ii) the facilitation influence on the subjects discussed, (iii) the process that adopt an idea, especially the arguments used by participants to defend their proposals, and in contrast, (iv) the 'evaporated' ideas, i.e. found in the audio records but not in the output from the tables, as well as the reasons for rejection. In other words, we had visibility on the inputs and the outputs of the work sessions but what happened inside the discussion was more obscure. Understanding the determinants for idea adoption or rejection may however explain some of the differences observed between the four tables.

One of the difficulty with this representation was to distinguish the different ideas, i.e. when did they start or end. A topic such as "diversifying species" (i.e. associated fruit trees) is too wide and is addressed throughout the design process. An attempt with table 3 transcript ended in a "moray-like" fish impossible to analyze (see appendix 9).

Along the same line as the moray fish, namely the topic in the fish head, the contribution into the fishbones, the constructive contributions above the backbone and the negative ones below, discussions were thus cut into sub-topics or concepts, we called 'ideas'. Each idea was represented by a fish and depicted a subject of discussion, a concept, e.g. aleatory tree seeding. The different types of contributions were distinguished with different color boxes: proposals in blue, positive arguments in green, negative arguments in orange, proposals transformed in 'Playmaïs©' in dark grey, lack of knowledge in purple, references in pink and 'facilitation voicing' or queries that are more neutral in white. We finally obtained a mind map with a shoal of fish spread over time (see Figure 18, p.34).

3. Results

To answer the question: 'How is an innovative on-station orchard co-designed?' there are three scales of results in this case study:

-Upon the global prototyping process with a focus on the workshop 2.0: the prototypes defined during the workshop, participants' satisfaction and Gotheron's understanding of workshop output.

-On the work session scale concerning participants' contributions, we analyzed four aspects: fields of expertise vs perceived contributions; perceived vs real contributions; the relationship between contributions and professional activities; and an analysis of types and nature of contributions.

-On the work session exchanges: To enhance this last analysis, we analyzed the series of the proposals throughout the discussions, followed by a deep analysis of the construction of ideas, to understand statements and 'evaporation' of some ideas. All of the results contributed to a finer understanding of the process of prototyping in groups, from which we can extract methodological learnings.

3.1. Prototyping process

From the prototypes designed during the workshop, we here described the four prototypes, how they were similar, how were they different and what did participants think of them. Then we considered the process of Gotheron prototyping, what they thought about the workshop results and the steps they took to build the final one.

3.1.1. Outputs of the workshop: Prototypes and satisfaction of participants

The prototypes in table 1 and 3 (Fig. 5 and 6) were very similar in terms of general design: there was a central pond surrounded by circles of fruit trees and a path that cut the circles by half. Table 1 justified circles through minimizing exchange surface with respect to climate variation and pests whereas table 3 thought about mechanization which avoids headland effect, i.e. turning at the end of the field. They had similarities in functions particularly about inter-rows: the cover should at some point be a barrier, a repulsive and fertilize the system. About similarities in composition, both prototypes integrate sorghum in their inter-rows, as well as hazelnuts, upper trees than apple trees and tansy. They also have in common that apple fruit tree cultivars are mixed on the rows. Finally, they both mentioned bird houses and perches added into the system.

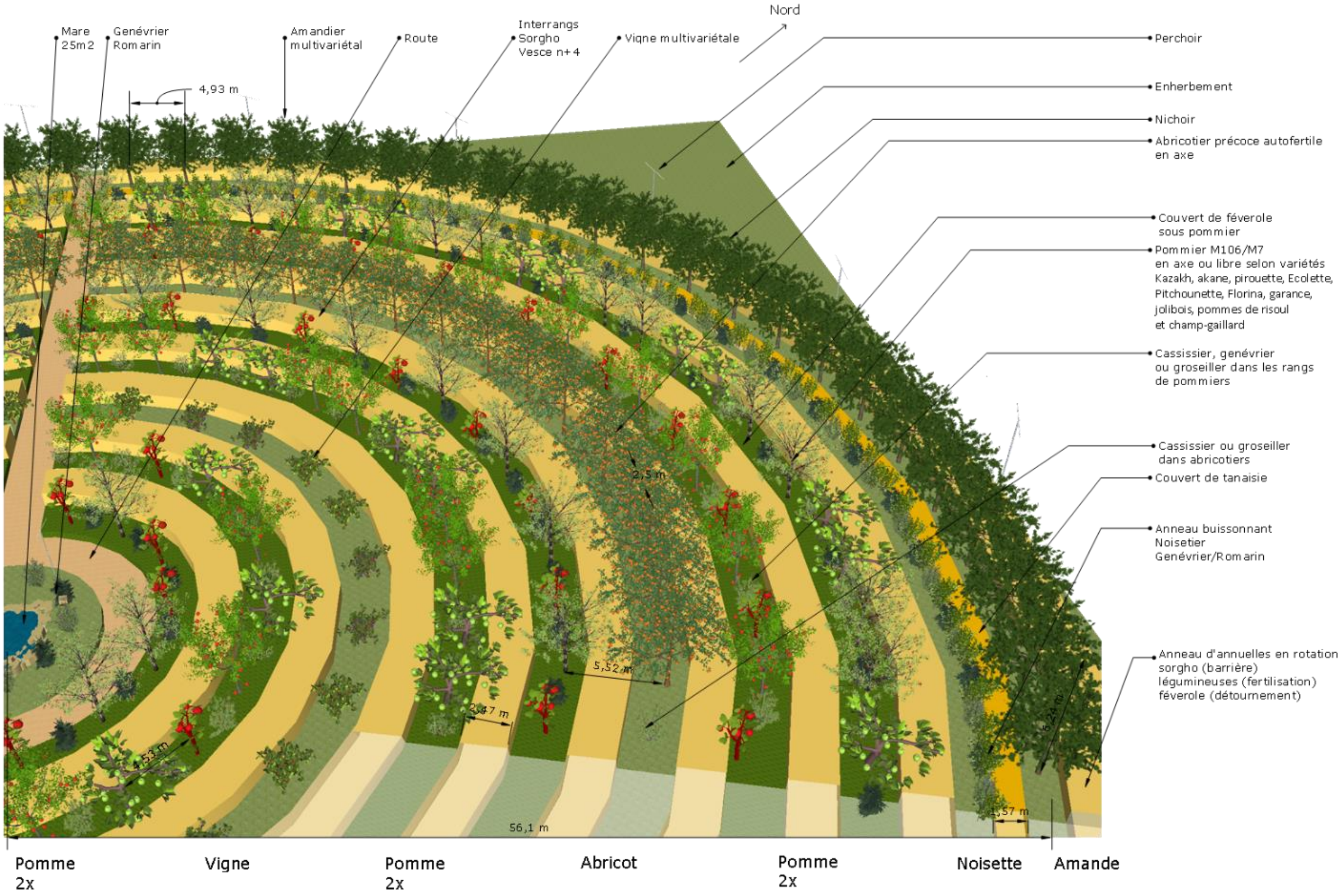


Figure 5 Computer-based prototype of table 1 (prototype 1)

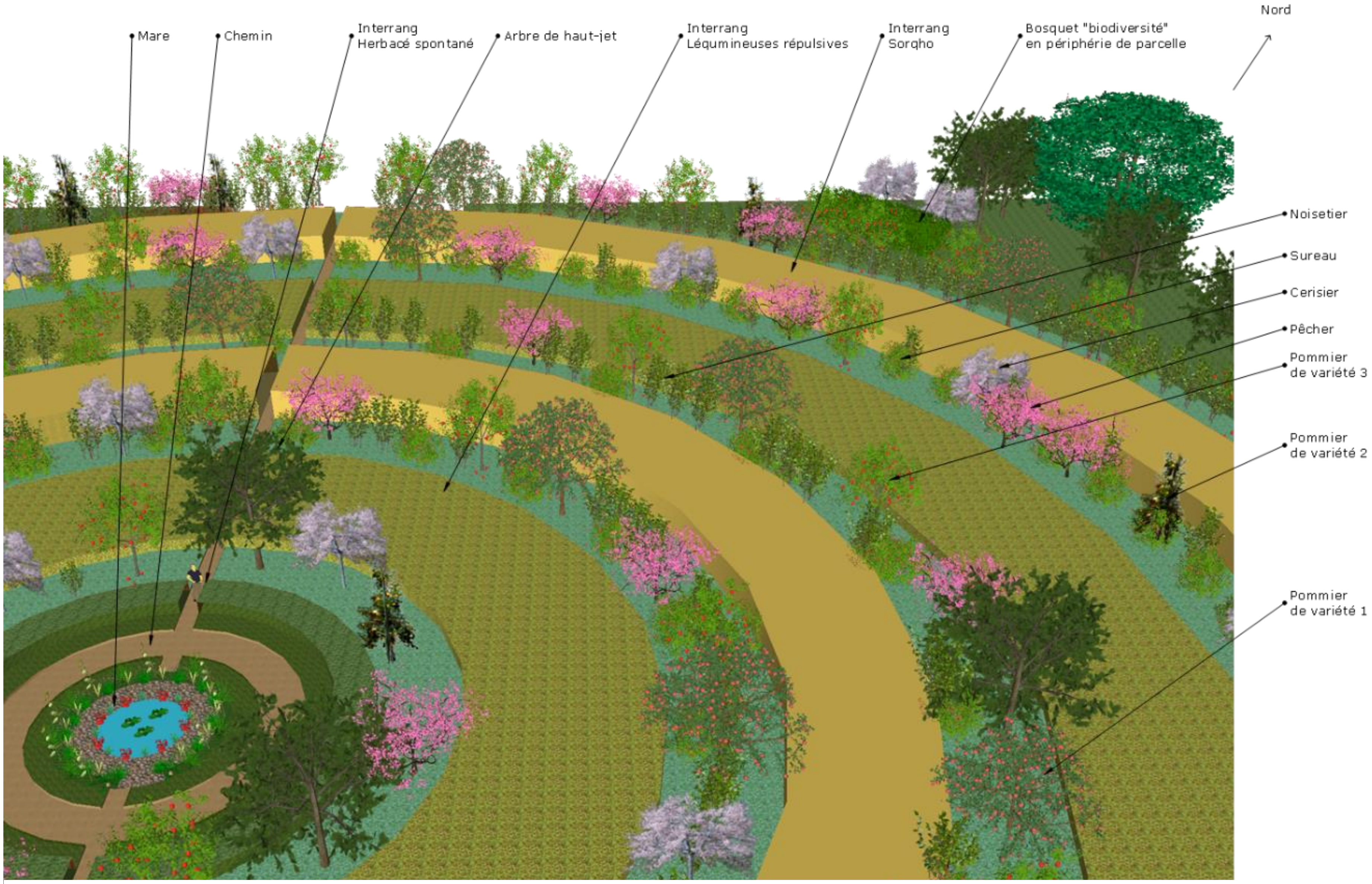


Figure 6 Computer-based prototype of table 3 (prototype 3)

What differentiates them however is the specific composition of the rows of trees: on prototype 1, one circle means one fruit tree species whereas on prototype 3, fruit tree species are mixed on the row, with hazelnuts and elderflower, following a ‘fruit hedge design’. Table 1 alternated small bushes on the rows such as black or redcurrants or juniper between fruit trees. The different fruit tree species implemented on prototype 3 were peach and cherry trees, whereas table 1 put from the outside to the inside, one row of almond trees, one row of apricot trees, 2 rows of apple trees and one row of table grape, each time between 2 rows of apple trees. Other differences were found in orchard design namely for inter-rows management: Table 3 defined three types of covers to manage inter-rows: one fertilizing and repulsive cover with leguminous plants and cov-releasing plants such as tansy *Tanacetum Vulgare* or wild mustard *Sinapis arvensis*, that are competitive enough with grass; a second type of cover is Sorghum with Soudan which is tall enough to create a potential physical interference for pests; a third type of management letting local adapted noninvasive plants grow. The three types of covers would be rotated in space and time. Prototype 1 on the contrary, integrates a year of vetch after sorghum every four years to bring some nitrogen into the system. Additionally, the first inter-row from the outside is a row of tansy in prototype 1.

Figures 7 and 8 show prototypes of table 2 and 4 which are both organized in islets. Other similarities in the composition and management are the integration of other fruit tree species into the system, especially cherry trees and raspberries, and that one islet embodies a single apple cultivar. Both integrate tall mixed hedgerows at the Northern edge of the plot and middle height mixed hedgerows at the Southern edge to break wind and optimize light interception.

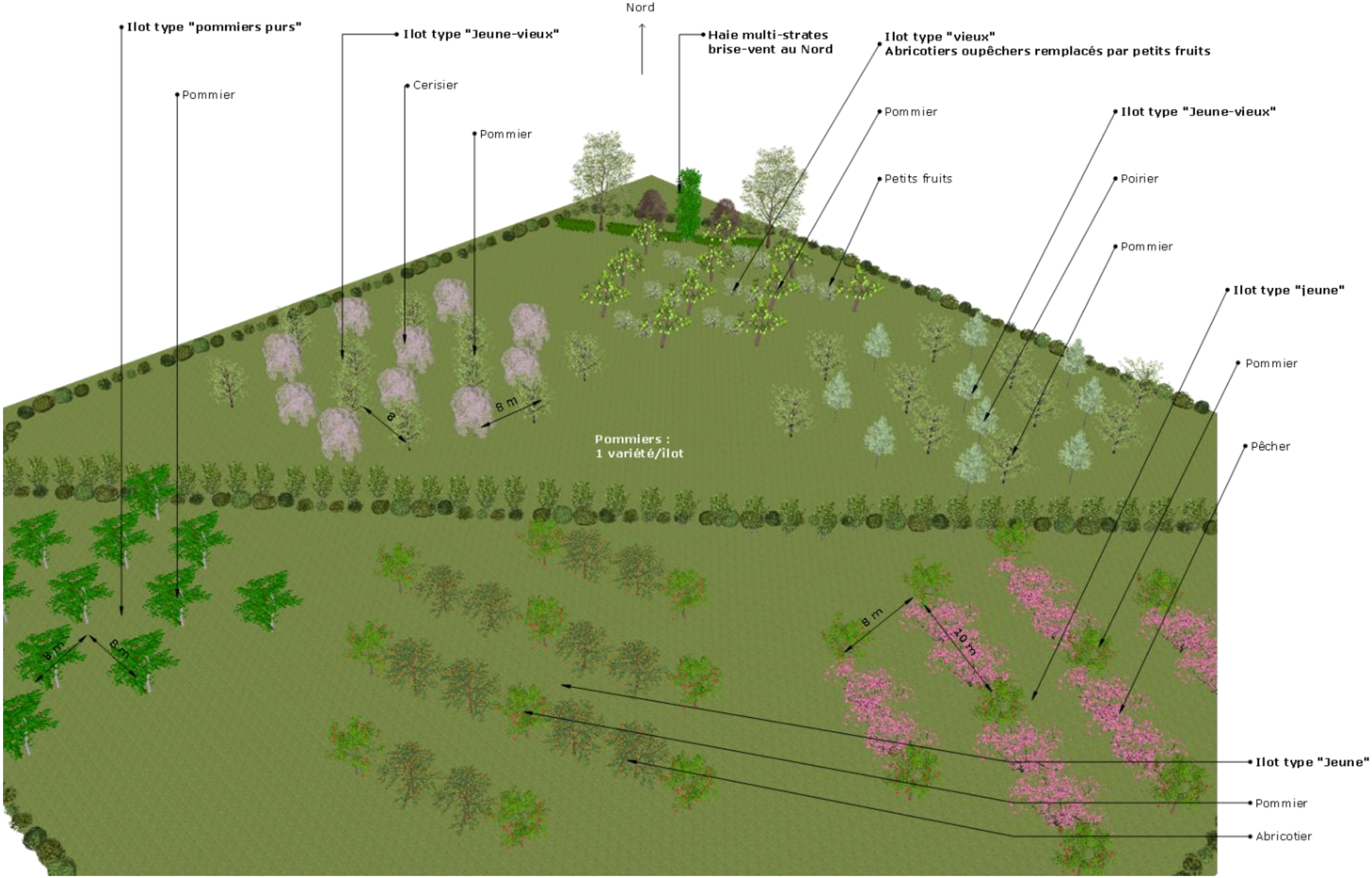


Figure 7 Computer-based prototype of table 2 (prototype 2)

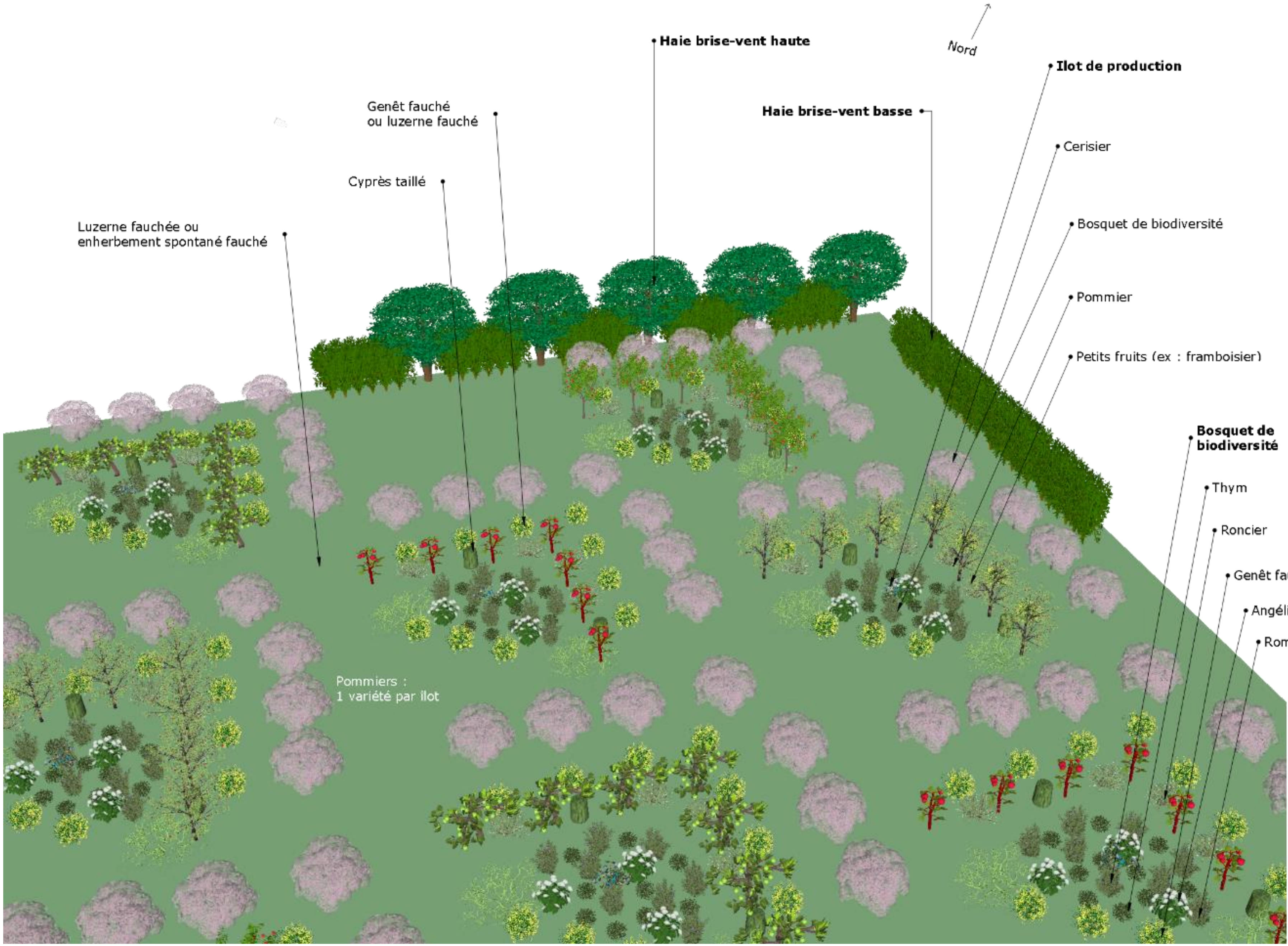


Figure 8 Computer-based prototype of table 4 (prototype 4)

What differentiated the two prototypes for the hedges is that table 2 wanted a continuum in the hedges in order to favor fauna movements. Therefore, lower hedges surround islets and cut the module in diagonal. They also differed in the shape of the islets. Table 4 would keep rows of fruit tree for working convenience but shaped them in V or chevron pattern. Each row of 8 to 9 apple trees would be completed by an outer row of cherry trees whereas on prototype 2, fruit trees were arranged in quincunx i.e. staggered rows with 10 to 20 apple trees. On prototype 4, the core of the V was composed of an area of biodiversity with angelica *Angelica archangelica*, rosemary *Rosmarinus officinalis*, thyme *Thymus vulgaris*, blackberry *Rubus fruticosus* and broom *Cytisus scoparius* to repulse pests, make natural bird places, feed pollinators or predators such as hoverflies *Episyrphus balteatus*. Table 2 mentioned wild carrots *Daucus carota* for hoverflies, Shepherd's purse *Capsella boursa pasteuris* for lacewings *Chrysoperla carnea*, sweet clover *Melilotus sp.* against vole *Microtus arvalis* and yarrow *Achillea milefolium* against sawfly *Hoplocampa* included in flower strips they did not feature on their layout. The group defined 2 types of managements of islets: apple trees mixed with cherry pear or plum trees that have approximately the same volume and are planted every 8 meters and managed as in prototype 2. Apple trees in islets with peach or apricot trees are planted every 10 meters and 2 peach or apricot trees are planted in-between, entering faster in production and which could be replaced by berries e.g. raspberries when apple trees would need more space. Table 4 mixed apple trees on the rows with pruned cypress *Cupressus sempervirens* and raspberries. Between islets, table 4 put alfalfa that would be mowed to force the predators of pests hosted by alfalfa to move on to the apple trees.

In general, the four tables talked about the need to break dominants wind i.e. Northern and Southern winds; with mixed hedges or groves and they all included the necessity to have a pond somewhere inside or close to the plot. They set preference on strong rootstocks for apple trees that allow roots to take nutrients and compete with grass, and maintaining the average tree height i.e. 4 to 5 meters to keep possible access without mechanization.

From the questionnaires, satisfaction about the designed prototypes differed. Prototype 1 satisfied 100% of the participants of table 1 (Figure 9). Table 2 however had a majority of mixed feelings on their prototype e.g. one participant specified that some compromises were not interesting.

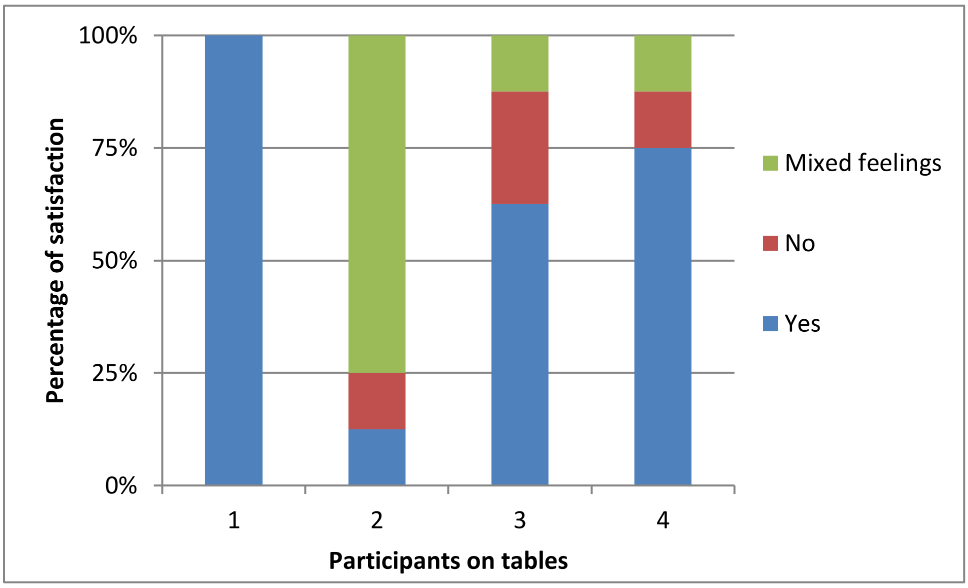


Figure 9 Satisfaction of the participants about the prototype they designed in the four tables of the workshop

Other reasons for dissatisfactory prototypes given in the questionnaires are e.g. the non-integration of animals, the non-accepted ideas due to feasibility, the lack of valorization of multi-production and its economic security. In addition, prototypes were not considered as 'finished' and could be improved with plant composition, technical aspects of orchard management, and crossing information with other prototypes and examples.

It is interesting therefore to understand what happened within the discussions to explain this level of differences among participants' satisfaction levels.

Regarding global workshop satisfaction, we were surprised by the enthusiasm of the participants to create a partnership to exchange knowledge, and some participants seemed more interested in having a recording track of the exchanges around the tables than getting a document containing only with output of the workshop.

3.1.2. Gotheron global prototyping process

Workshop debriefing

After the workshop, the Gotheron team debriefed their feelings on the output. Some members were disappointed by output regarding their table, their prototype was far from complete as well as an over voicing of some participants that lead the discussion in their way e.g. persons that have no experiences or who are not innovative enough. Therefore, those members were reserved about the necessity of doing workshops with experts (outsiders) to design a module. To them, the participants cannot have a holistic view on the system to create in half a day, regarding the issues and the components to integrate and design an orchard in only one and a half hour. The Gotheron team particularly, had already defined some components they would integrate or not into the system although almost all other participants started with a blank page. One member said, "this workshop arrived two years too late!" On the contrary, some other members were surprised by the novelty of the spatial arrangements, and that two of them were so similar (table 1 and 3).

Re-appropriation of the workshop outputs and final design

Regarding the final prototype made by Gotheron, after setting dates for a succession of meetings, the objective of the first meetings was clearly to appropriate themselves the outputs from the workshops. Therefore, a compilation of the rapporteurs' report as well as using the SketchUp© pictures helped them to understand the details of each prototypes and the main explanations of the components of the prototypes. Their process to express their decisions was to listen to the opinion of every members around the table and often followed by a counting of voices for or against a proposal.

The process to take decisions was long at the beginning but surprisingly more effective once the global design was decided. It required seven three-hour meetings to hand out a prototype that satisfied all members. The steps to define the prototype were: (i) the global design, (ii) the number of 'rows' and the functions of the external and the center rows, (iii) the number of pathways and the management of the different species/cultivars, (iv) the number of cultivars of apple trees, (v) fruit trees associations and finally (vi) apple tree cultivars.

There was a clear a shift after they chose to start from the circular prototypes of the workshops, in the manner in which they proceeded to design and state components. They needed to disconnect global design of the prototypes with the levers implemented in order to do the design exercise themselves. Indeed, each member needed to define and express what they wanted. There was a session especially where each member had to think personally and propose a drawing about how they would compose and manage the apple trees and the fruit trees in the circular system. The meeting after this session was especially efficient because components to integrate were less debated allowing us to arrive at a consensus quickly to express decisions. One element that helped is that one member had worked in between the two meetings to propose a layout based on the main ideas that seemed satisfying. My internship stopped one session after this last one and even if the prototype is not finished yet, we already had a good overview of the system. What remains to be decided especially is the management of the inter-rows as well as other common orchard operations, and several cultivar and species names matching the functions desired, e,g, in the fruit hedge, or the rusticity proprieties of the genetic resources.

Figure 10 is a picture of the prototype of Gotheron as it was when I left. The circles were divided by three pathways, joining a pond at the center. An external circle (i.e. R9) made of biodiversity elements would surround the system and create an initial barrier. A second circle (R8) is composed of trap trees against rosy apple aphid thanks to the cultivar Florina which is resistant to this aphid. It is mixed with Akane cultivar on the row. R7 is composed of another circle of 'birscher-müesli hedge[1]' with fig, almond, hazelnut and grape trees. From the circle R6 to R1, the circles were managed the same way: each circle was divided in thirds by the three pathways, then each third was again divided in two to alternate non-apple fruit trees and apple trees on the row. Each portion of a given fruit tree alternates two cultivars mixed on the 'row'. Each

[1] Gotheron observed the bircher hedge on a farm but it was studied by students at HEPIA Switzerland: http://docplayer.fr/14248337-Agr-flash-agronomie-hepia-novembre-2012.html

couple of apple cultivars or species is organized in spiral stairs: each time the fruit trees shift on the row, workers should move to the internal circle. This way, management is easy to remember and to follow, and there are similar numbers of trees (and therefore a similar volume in fruit production) regarding apple cultivars (instead of having one cultivar per circle). Moreover, pests should be unsettled by fruit tree shifts on the circles and cultivar mix. Each couple of apple cultivars is chosen regarding a similar period of harvest. There are therefore 8 apple cultivars in the system if we count Florina and Akane, and three fruit tree species conducted in spiral: peach, apricot and plum trees with two cultivars each. To finish nearby the pond, there will be a circle (R0) with some table grapes and/or other low trees in order to allow pathways for bats, birds

and pollinators.

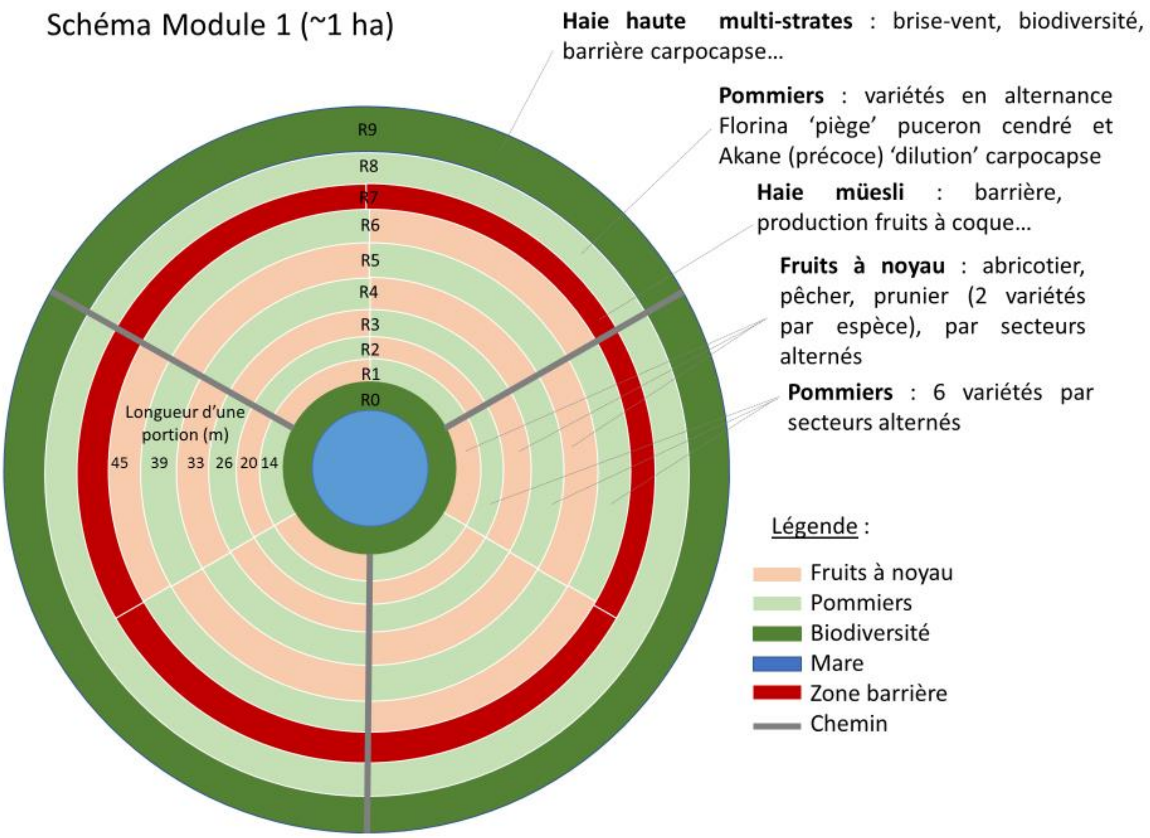


Figure 10 Final prototype made by Gotheron. In orange, the stone fruits, in light green, the apple trees, in dark green, agroecological infrastructures, in blue, the pond, in red, a 'barrier' zone and in grey, the path

After presenting the results on the overall process of prototyping, we can focus more specifically on what happened during the workshop. Our area of research concerns participants' contributions regarding specific elements of their profile and their perceptions about it, and the construction of ideas.

3.2. Workshop contributions

In this part, we firstly compared the fields of expertise with the perceived contributions, then the perceived contribution with the real contributions and finally we compared the different types and nature of contributions regarding professional activities and tables.

3.2.1. Fields of expertise, perceived contributions and real contributions

Eight topics were suggested to the participants in the multiple-choice questionnaire before and after the work session (before on their field of expertise, after on their perceived contributions) with a category ‘others’ that has been selected by some participants to add new fields of expertise in commercialization and in co-design methodology.

Fields of expertise and perceived contributions

Figure 11 shows differences between people’s skills (approximation from fields of expertise) and in what they thought they had contributed after the workshop, on the same topics. First, we can see that the topics biodiversity, plant associations and orchard management were the most answered ones, meaning that we had gathered people to the workshop having those main fields of expertise and perhaps knowledge in these topics.

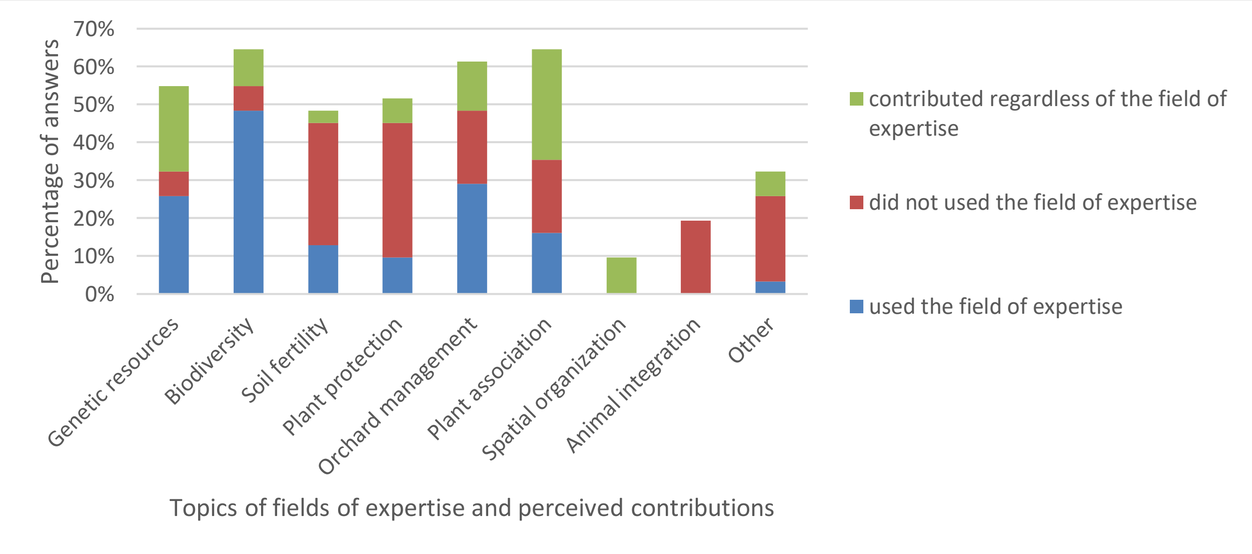


Figure 11 Difference between fields of expertise and perceived contributions

Three patterns stand out: biodiversity and on smaller- scale orchard management were the categories was the most in adequation with people’s skills and perceived contributions. In contrast, the categories ‘plant protection’, ‘soil fertility’, ‘animal integration’ and ‘other’ (i.e. mostly commercialization and co-design methodology) were considered as underused by the participants, which is not surprising regarding the fact that we asked them to create a system without pesticides, without animals and that commercialization was not a lever considered at this point. This means as well that people who considered themselves as having those skills, could not elicit their knowledge. Results are surprising when looking at soil fertility which was one of the ecosystem services aimed by the project and which seemed to be underused during the work session, maybe due to our approach and directives focused on pest suppression. Finally, the categories ‘plant associations’, ‘spatial organization’ and more surprisingly ‘genetic resources’ had a high proportion of contributions outside the fields of expertise; this could mean that it is not the main skill or field of expertise of participants and/or that a general knowledge about those topics can lead to proposals during the workshop.

Real vs perceived contributions

Figure 12 shows the gaps between topics on which propositions have been recorded and topics participants thought they contributed to.

Except for biodiversity, participants generally underestimated their contribution, since proposals existed but participants thought they had not contributed within the topic. It is interesting to see that participants underestimated their real contributions in soil fertility whereas at the same time they considered they poorly used this field of expertise (see Fig. 11). This may be related to our categorization which included grass competition and soil detoxification (e.g. Sorghum of Soudan) in soil fertility.

Scarce overestimation of contributions could also send back to categorization. The broad proposed categorization (e.g. plant protection was included in orchard management) could also contribute to the observed results.

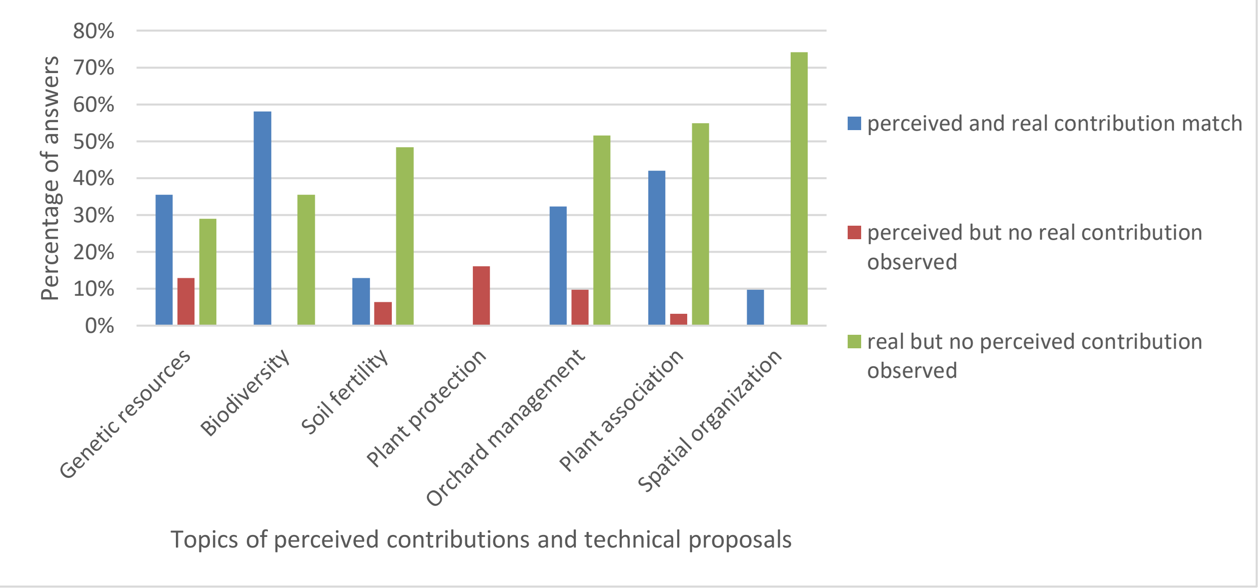


Figure 12 comparison between perceived contributions and technical proposals

3.2.2. Real contributions analysis

Number of contributions per professional activity and table

Concerning real contributions, the analysis considered the number of contributions per person, the differences among tables and particularly, the type and nature of contributions compared to professional activities.

Firstly, the number of contributions was not homogenous between participants, between professional activities and between tables (Figures 13 and 14). In general, farmers, advisors (i.e. advisors, farm group leaders), experts (i.e. biodiversity experts and key informants) were the three categories that most contributed. The most 'non-talkative' and homogeneous categories were the organizers (animators and Gotheron team) with a low rate of participation, which is related to their role of support rather than contributors. The researchers and experimenters' category contributed at an intermediate level but relatively homogeneously in terms of number of contributions per person (low standard deviation). All stakeholders included in farmers' category participated at least 50 times which could indicate that farmers are a solicited category regarding agroecosystem design. Farmers' intermediaries, farmers and experts were categories in which the level of contribution varied widely, from the more discreet participants, to the participants that contribute the most. Trainers were analyzed in a separate category because trainers didn't express themselves very much. However, we had only three participants that are categorized as trainers and we cannot draw conclusion.

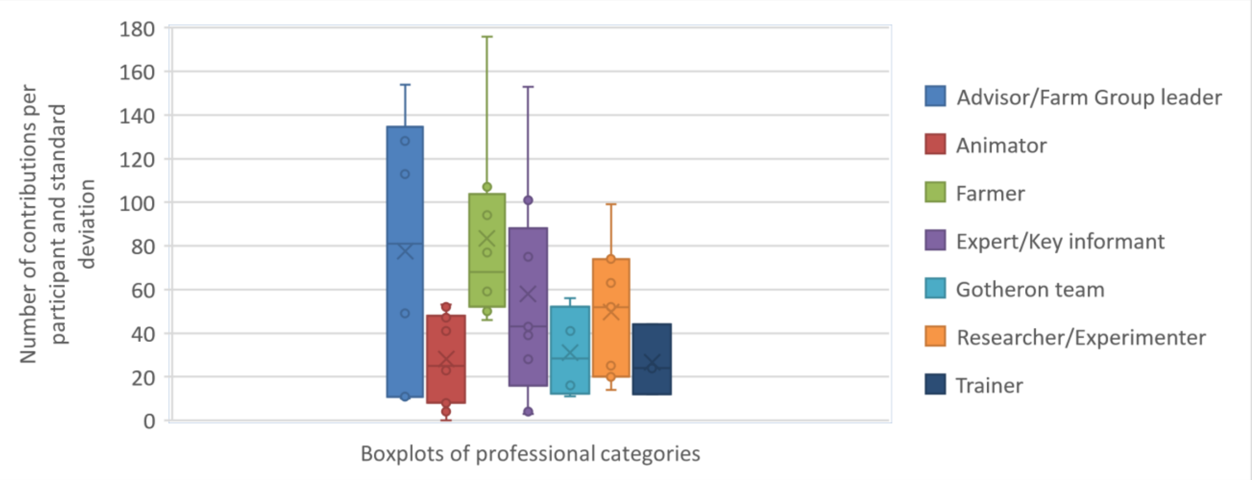


Figure 13 differences in participation between different professional activities

It seems that people talked less often per person on table 4 and 3 than on table 1 and 2. (Fig. 14). Of course, since the duration of each speak is not considered, this variable rather measures the 'pace' of exchanges than the total contribution time. In general, differences in the number of contributions per person were noted whatever the table. The most homogeneous tables are also table 3 and 4, which have the smallest standard deviation, meaning participants may had more equal speeches allocation.

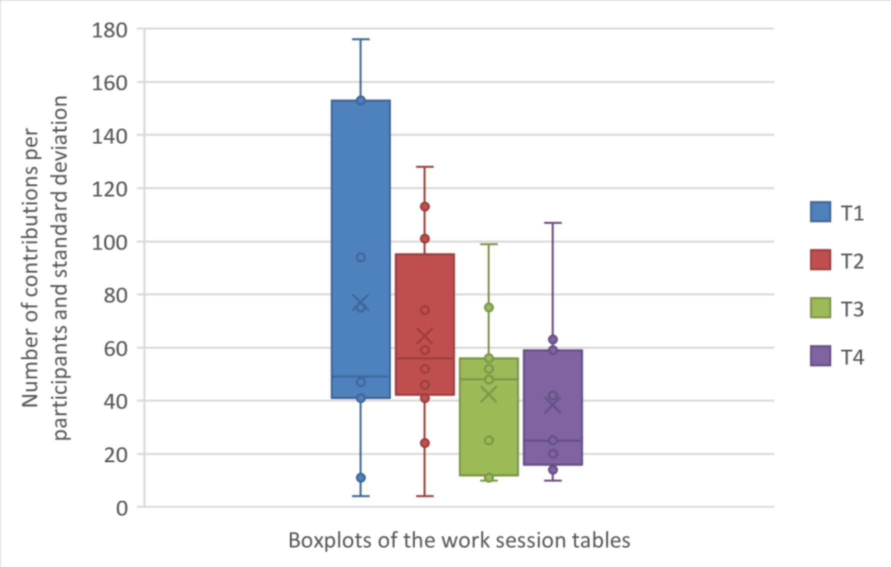


Figure 14 differences in participation between tables

Later, the different types and nature of contributions per professional category (see Table 1 in §2.4.2) and table were analyzed regardless of differences in participation.

Analysis of contributions and table outputs

The analysis addresses the differences regarding the types and nature of contributions per table and the way those differences could explain the differences or similarities between prototypes, and also the rate of satisfaction among participants. (see Figure 9 in §3.1.1).

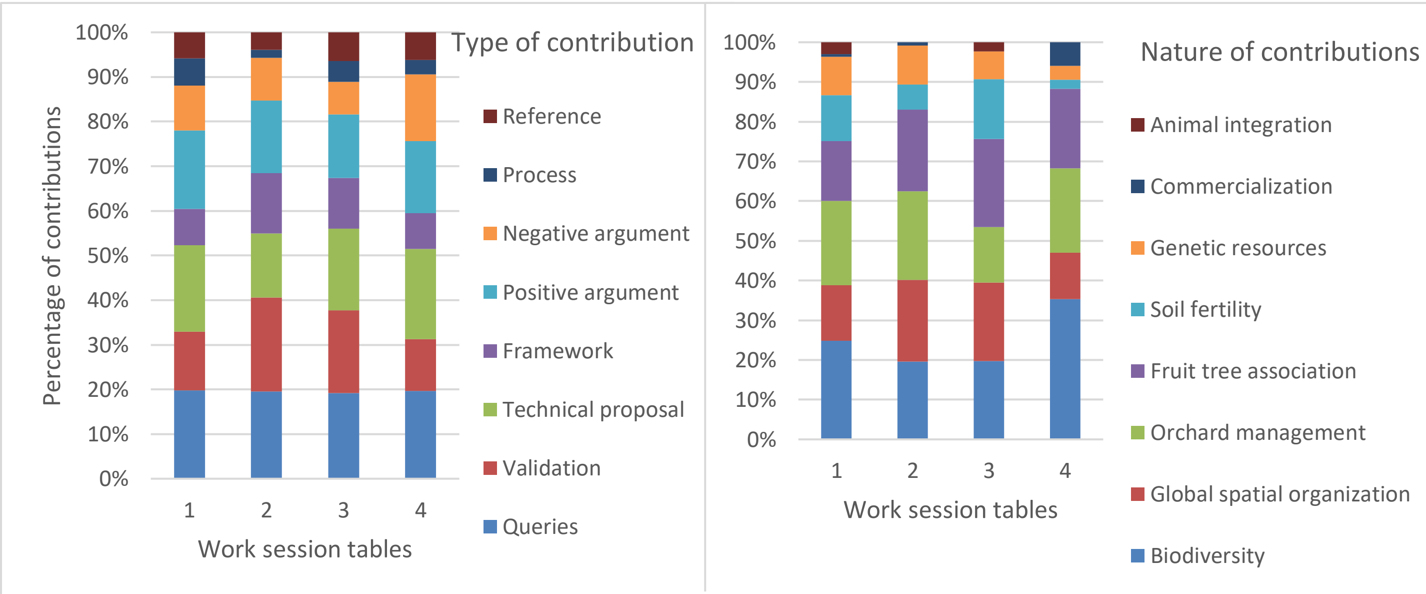


Figure 15 types and nature of contributions regarding tables

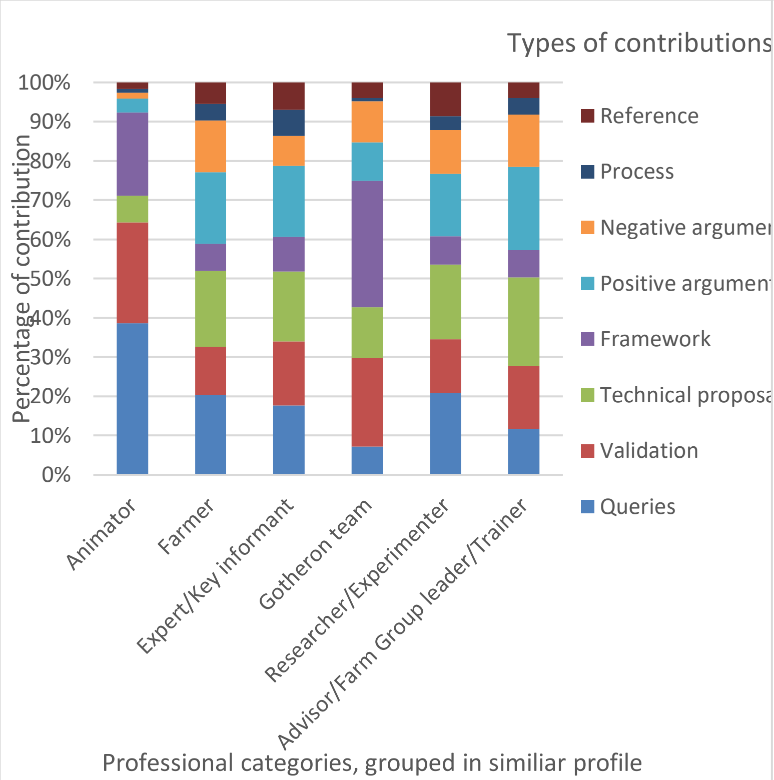
All of the tables adressed all of the topics in similar proportion (Fig. 15). Firstly, tables 1 and 4 tended to bring more technical proposals whereas tables 2 and 3 discussed more about framework. Tables 1 and 3 brought a bigger amount of references and processes and table 1 has a greater amount of positive arguments whereas table 4 has a greater amount of negative arguments. Surprisingly, all tables had the same amount of queries (20% of the contributions), which make us hypothetize that questions are necessary to all group work and which may be independent of the outputs. What could be observed on tables regarding outputs however, is: first of all on table 1, the numerous technical proposals were supported with positive arguments, processes and references, which didn't require numerous explicit validations. On table 2 on the other hand, technical proposals were debated and therefore increased contributions of framework and validation type. Similarly, table 3 had a relatively larger amount of technical proposals, references and processes defined, counter balanced by discussions around framework which needed validation. Table 4 had the greatest proportion of technical proposals, new ideas, counter-balanced by a consequent proportion of negative arguments and fewer validation.

Regarding the topics of the technical proposals, the three categories having the highest proportion of contributions are biodiversity, fruit tree association and orchard management. This result matches with the the most numerous fields of expertise brought in the workshop (Fig. 11), i.e. biodiversity, plant association and orchard management, which confirm that fields of expertise of participants may correspond to the topics discussed in the work session and therefore the knowledge produced.

The three first tables matched the same proportion of biodiversity (20-25%) whereas table 4 proposed more agroecological infrastructures, companion plants or ecosystem mimicry e.g. aleatory fruit tree seeding and forest border effect, but scarce discussion about genetic resources. Tables 2, 3 and 4 discussed or defined more fruit tree association (other than apple tree) than table 1 whereas prototype 1 seems to include more fruit tree species. This result may imply that outputs are not necessarily representative of the topics discussed. Indeed, sometimes participants disagreed and needed to arrive at trade-offs to propose in between solutions or new ideas from dead ends, which gave only one output but many points of discussion. Finally, table 1 and 3 integrated more soil fertility elements and animal integration (even as jokes) than table 2 and 4 which, however discussed, about commercialization.

Contributions and professional activities

Figure 16 shows first that validation and contextual indications elements are mainly attributed to animators and Gotheron team according to their role of facilitation. Queries were also very common to animators aiming to clarify participants' proposals or assertions. However, contrary to our hypotheses, everybody contributed to creating the system, even the organizers that sometimes proposed new elements. In addition, everybody contributed to facilitating discussion and expressing decisions. For example, in one group, a participant said to a strong personality: "*mais laisse le parler* (i.e. let him speak)" speaking of a young and introverted farmer; in another group, an experimenter said "*donc on va voter, puisque personne n'est d'accord* (i.e. let's vote then because nobody agrees)". Contrary to our expectations, references and processes were not greatly used in, but were mainly provided by experts, key informants, researchers and experimenters.



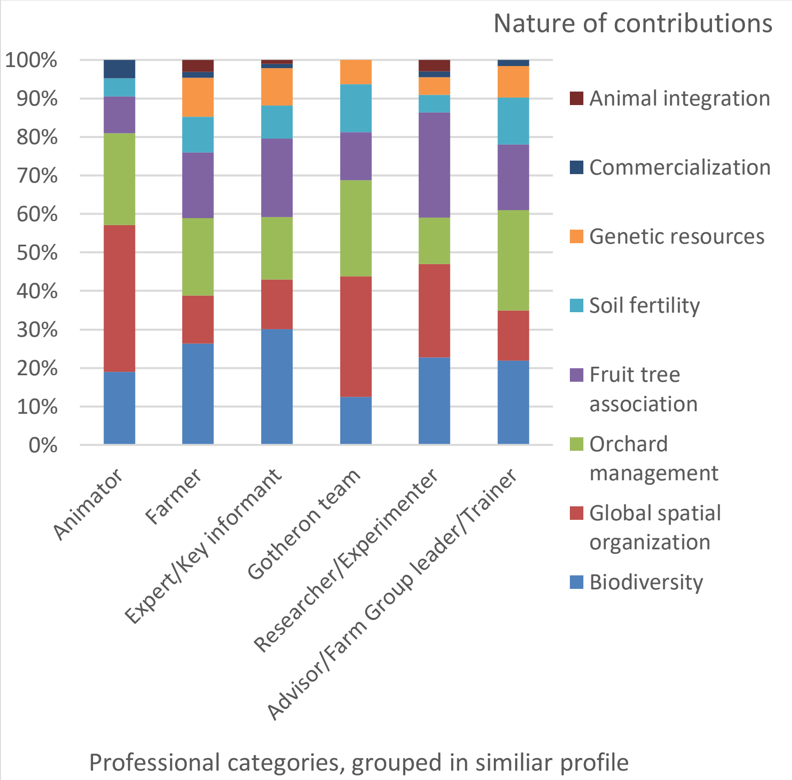


Figure 16 types and nature of contributions regarding professional activities

The professional activity does not determine the number nor the types of contributions. Generally, professional activities are quite similar in the topics discussed. When organizers made new proposals, it was mostly about global spatial organization or orchard management, some said it was in order to reach compromise and make discussion move forward, or to propose a management that could be feasible on Gotheron. Finally, looking closely, 'farmers' was the most homogeneous category in the proportion of topics tackled, even animal integration or commercialization. This could attest that farmers have a good knowledge of all components of agroecosystem and/or that designing an agroecosystem needs to have a holistic approach and does not focus on one type of component (e.g. genetic resources)?

3.3. Ideas construction, statement and ‘evaporated’ ideas process understanding.

3.3.1. Timelines of the topics of the proposals throughout the work session

After this quantitative analysis of contributions, we addressed the order the topics had been discussed. Indeed, topics could be discussed one by one or grouped in a holistic discussion.

Therefore, we used the lines of the transcripts to extract technical proposals from our data base and approximate a ‘time’ during the work session by calculating a percentage of progress (see §2.4.3). There was no differentiation however between ‘evaporated’ and accepted ideas on timelines (Fig. 17). It is interesting to compare topics between them as well as between tables, especially the topic sequences and namely their capacity to address multiple topics in a short period of time.

In general, ideas were grouped on biodiversity at the beginning and fruit tree association was relatively brought at the end, whereas orchard management was integrated all along the work session. Tables proposed more items on biodiversity, fruit tree association and global spatial design in accordance with the ‘rules’ of the exercise and figure 15. But orchard management, soil fertility, genetic resources and even sometimes commercialization were systematically addressed to design a consistent system.

The first table started rapidly with numerous proposals in diverse topics: biodiversity, fruit tree association, spatial organization and soil fertility integrating orchard management. The table integrated numerous topics near the end of the work session especially in genetic resources. Table 3 had a similar pattern of integrate topics, with a hollow of proposals around the middle of the work session more focused on a few topics. Table 3 however took more time at the beginning to discuss about the framework, and focused on the global spatial organization after the ‘gap’ in the middle of the work session. It is interesting to notice that the two tables that had similar design outputs also had a similar topic sequence. Table 2 addressed topics in a successive and gradient way. At first, they proposed ideas on biodiversity, then on spatial organization, orchard management and fruit tree association. Afterwards, they talked for a long time on genetic resources before integrating all the other topics focusing especially on fruit tree association, then on soil fertility and finally on biodiversity. Table 4 in contrast, had the opposite approach: at first, participants focused on global spatial organization integrating more and more items on agroecological infrastructures, agroecological management or companion plants, genetic resources, fruit tree association, orchard management and soil fertility, to finish the work session on a few proposals about commercialization, fruit tree association, biodiversity and orchard management.

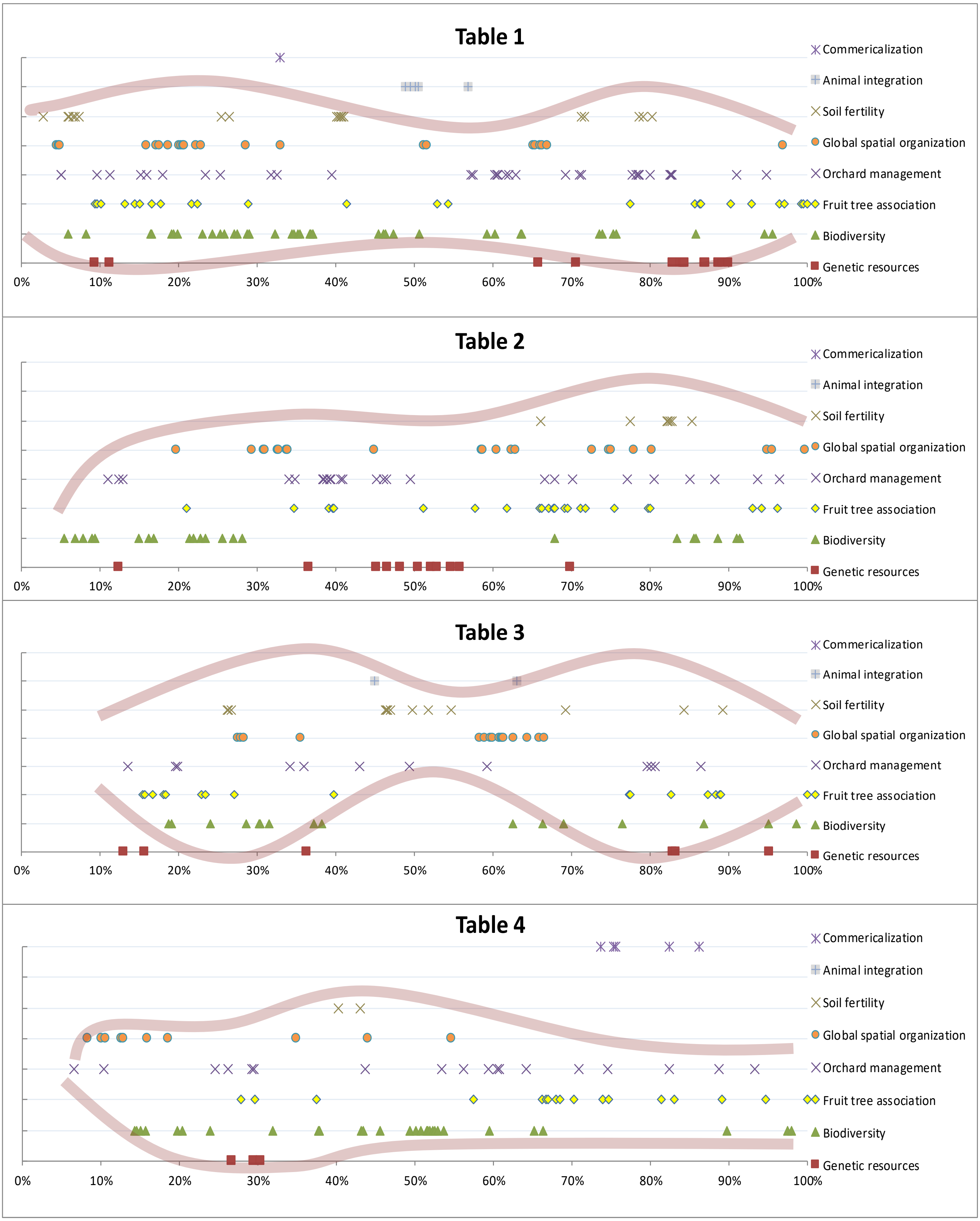


Figure 17 Timelines of the topics of proposals per table, through the time of the work session, regardless of the final status (i.e., kept or rejected) of proposals

3.3.2. Ideas development and evaporation

Our initial hypotheses concerning the construction of ideas were (i) the idea starts with a proposal followed by a justification. (ii) the idea is confirmed or supported with references, (iii) the idea is challenged and then (iv) reconfirmed. The final step (v) should be the realization of the idea on the spatial layout or on the rapporteur report. The process of the construction of ideas is however more complicated.

The analysis focused on the sequence and development of ideas to understand how proposals were generated, explored, assessed and selected, ie adopted or rejected. Figure 18 presents the nine global ideas discussed on table 4 along the work session that we represented in nine fish.

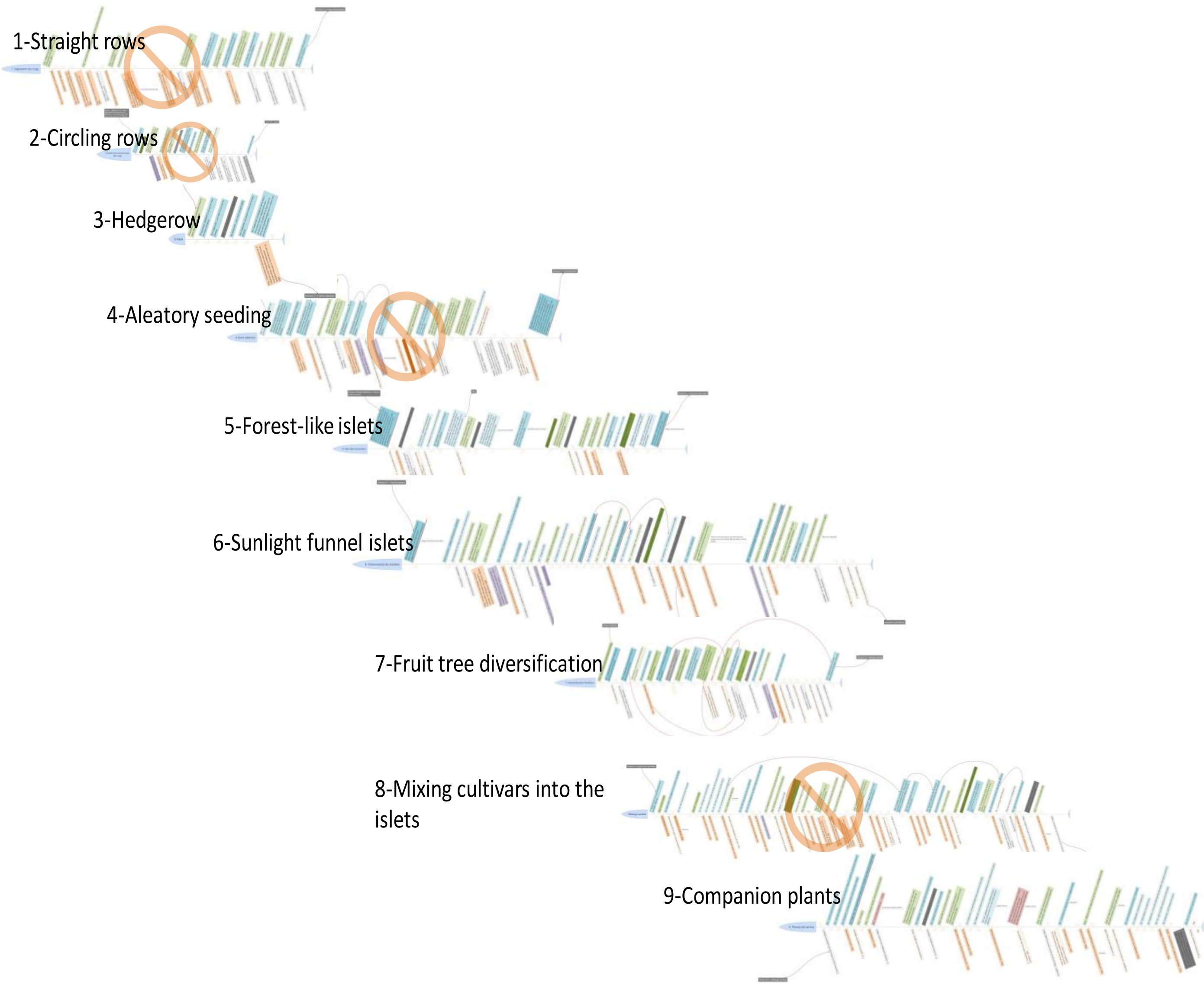


Figure 18 order of construction of ideas on table 4

As a reminder, each fish represented an idea and its development thereafter, fish heads represent the start of a new idea, fishbones represent the discussion taking place on the subject (with colored types of contributions), including all types of contributions that can be constructive (upper fishbones) or put into question (fishbones below backbone) as well as more neutral contributions (not colored). Fishtails suggest the end of one subject and announce the beginning of a new idea. Finally, the shoal of fish represents the overall succession of the ideas.

Table 4 is especially interesting because the group introduced several ideas that were either evaporated or evolved (fish with prohibited sign on figure 18). Some ideas were in fact not adopted because proposals were too much ‘out of the box’ or didn’t suit Gotheron requirements.

One accepted idea and one evaporated idea are here finely detailed: the sixth fish, sunlight funnel (Figure 19) and the eighth fish, mixing cultivars into the islets (Figure 20) among the 7 others that were less debated topics (the other fish are shorter and can be found in Appendices 10 to 16).

1- Straight rows fish

From the timeline of table 4, participants started to discuss the global spatial organization. More precisely, they debated as to whether fruit trees should be lined up or not. On one side, participants especially farmers were skeptical about innovative design because rows are the most practical for work organization and efficiency, and they therefore questioned the advantages of no rows in the system. On the other side, other participants wanted to try innovative design because “*c’est en faisant qu’on aura la réponse* (i.e. it’s by doing that we will get the answer)”. Finally, the assertion: “avoir un agencement innovant permettra de sortir des contraintes opérationnelles (i.e. new design will free the group from operational constraints)” decided the group on trade off proposals: fruit trees lined up with companion plants or curves in different direction which is the subject of the next fish. Indeed, the proposal of curving rows north-south and east-west directions was amended by successive considerations supporting biodiversity with the notions of organization in ‘siphon’ with ‘crossroads’ of ecological corridors that made consensus.

2- Circling rows fish

This discussion about global spatial organization opened a serie of queries about the context, the surrounding environment and the approach of Gotheron. The fish and the idea ends with a shift of subject to talk about hedges but participants shifted quickly again to discuss a new idea (‘aleatory seeding’).

3- Hedge fish

The fish ‘hedge’ is short because assertions made consensus on the necessity to plant hedges, especially as buffer zones but the discussion switched from spatial design to plant health and evaluated as more important to find a naturally balanced forest-like system.

4- Aleatory seeding fish

The idea of seeding the orchard trees was supported by one participant who proposed several alternative proposals for this idea in answer to multiple critics, for instance 'on ne va pas semer des pommiers. (we won't seed apple trees). The discussion ended on an alternative proposal, as trade-off between the original idea of a forest-like system with minimum disruption and the benefits of aligning fruit trees (the first two fish).

"*Donc moi, j'aurais plus tendance à imaginer une forme qui soit proche d'une lisière, peut-être avec des courbes, et partir quand même sur du scion parce qu'effectivement, je pense que ça va être compliqué et long et on n'est même pas sûrs que finalement, on ne se retrouve pas avec une espèce de forêt qui produise plus de bois.* (I would be more incline to imagine a shape close to a forest border, maybe with curves, and beginning with [fruit tree] scions because it would be long and complicated and unsure finally that we will not get a forest producing more timbers)".

5- Forest like islets'

A new idea started, 'the forest like islets', back to spatial organization with a new proposal based on 'crossroads': a square of 9 fruit trees with companion plants in the middle and alfalfa in-between islets. The discussion here was very constructive without negative arguments and supported with bibliography (on '*pest suppressive approach*'), empirical knowledge ("*I did*…") and theoretical references ('*permaculture*').

6- Sunlight funnel islets

The idea evolved when a participant proposed to open the southern part in a shape of a 'well of sunlight' to optimize sunlight interception which is a classical design in permaculture (Figure 19). Participants appropriated the concept by reformulating the idea in a 'funnel of sunlight', the global idea discussed in this fish. The proposal was enriched with proposals of names of 'repulsive' plants. Lacking knowledge regarding the capacity of the plants to regulate pests was also outlined (Fig. 19).

The discussion switched then to deal with the problem of preventing pest infestation, which led to proposals of hedges into or around the plot, but a participant underlined that Gotheron had already thought of a cord of agroecological infrastructures. Participants also decided to put a Northern hedge against dominant winds.

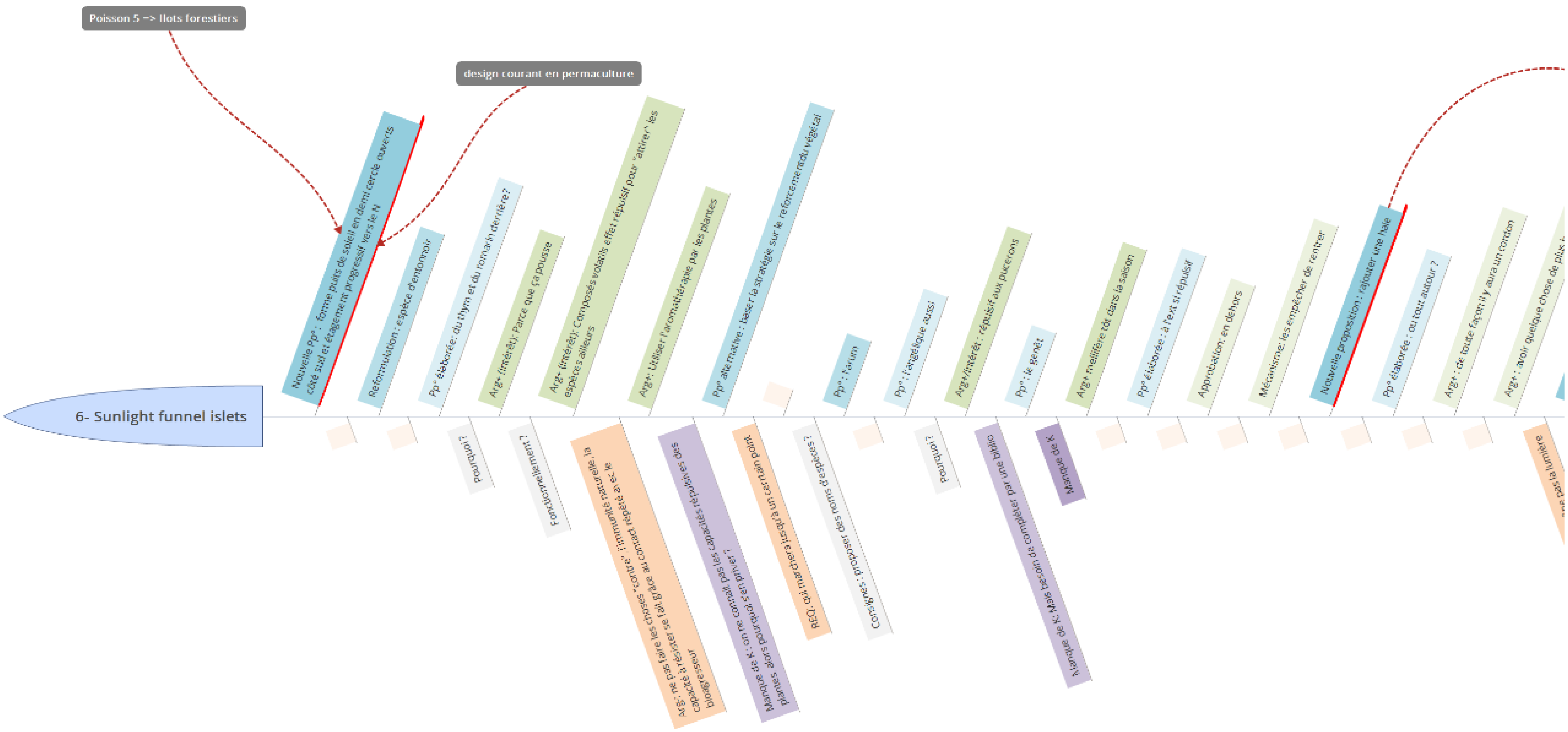


Figure 19 The sixth fish-idea of table 4, ‘sunlight funnel islets’, part 1

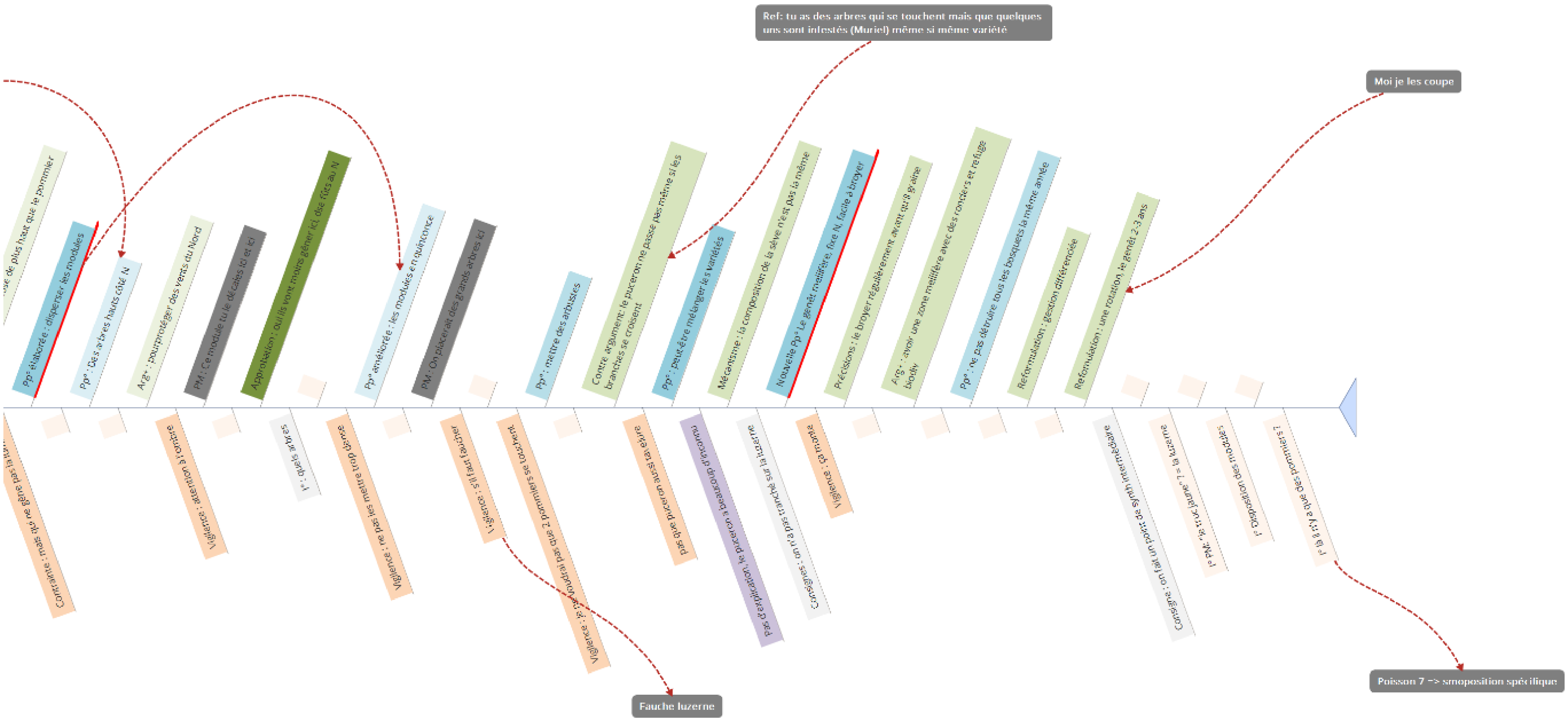


Figure 20 The sixth fish-idea of table 4, ‘sunlight funnel islets’, part 2

The second package of bottom fishbones (Figure 20) was not real critics but items of attention concerning density and disposition of the islets for light competition, cultural practices and pest management. Participants therefore, proposed to have islets in quincunx and that two apple trees should not be contiguous. This last proposal was counter-balanced by an empirical reference by an experimenter who had seen rosy apple aphid infestation stopped with no other explanation than the low-susceptibility of apple trees and tree sap composition "*Non parce que quand même moi j'ai des arbres qui se touchent et le puceron s'arrête à celui-là. […] Aucune explication. Le puceron, on a toujours beaucoup d'inconnues* (No, because I have contiguous trees and the aphids stopped at that one […] No explanation. With aphids, we always have numerous unknown factors)". Discussion was interrupted by the facilitator who wanted to make a decision on alfalfa (previously discussed), which brought propositions of managing broom instead of alfalfa, for nitrogen and pollinators (as leguminous and melliferous plants) but which has the disadvantage of over-spreading. The proposal evolved into a differentiated management of broom every 2-3 years. Finally, an intermediary synthesis closed the discussion and opened to new queries on specific composition.

7- Fruit tree diversification

The next fish started with the idea to reproduce the forest edge effect (processed at the origin of the 'forest-like islet' fish) by planting upper cherry trees for fruit tree diversification. However, ideas telescoped after this, sometimes about integrating berries, sometimes coming to mixing cultivars, which gave the feeling that participants lose the train of thought. This was supported by the fact that the discussion turned into successive questions that went in every direction, but which was finally refocused thanks to the Playmaïs© layout, with a question about the color of the apple tree representation.

8- Mixing cultivars into the islets

The fish "**mixing cultivars**" (Figure 21) was the subject that was the most debated. On the one hand, participants wanted to diversify cultivars of apple trees within the islets, whereas on the other hand, participants wanted homogenous islets because it was complicated to manage mixed cultivars, especially during harvest. This led participants to talk about commercialization (Fig. 21) and an alternative marketing outlets proposal instead of long channels, e.g. boxes with apples of different colors sold in CSA (i.e. Community Supported Agriculture) farms (AMAP equivalent in France – Association pour le Maintien d'une Agriculture Paysanne), which permitted to mix cultivars within each islet with no need to differenciate apples at picking or for sale. However, the sale of mixed apples is not permitted according to the current legislation, and even after several attempts of persuasion for mixed islets, the group finally opted for the "reasonable" choice of mono cultivar islets associated with diversified stone fruit trees.

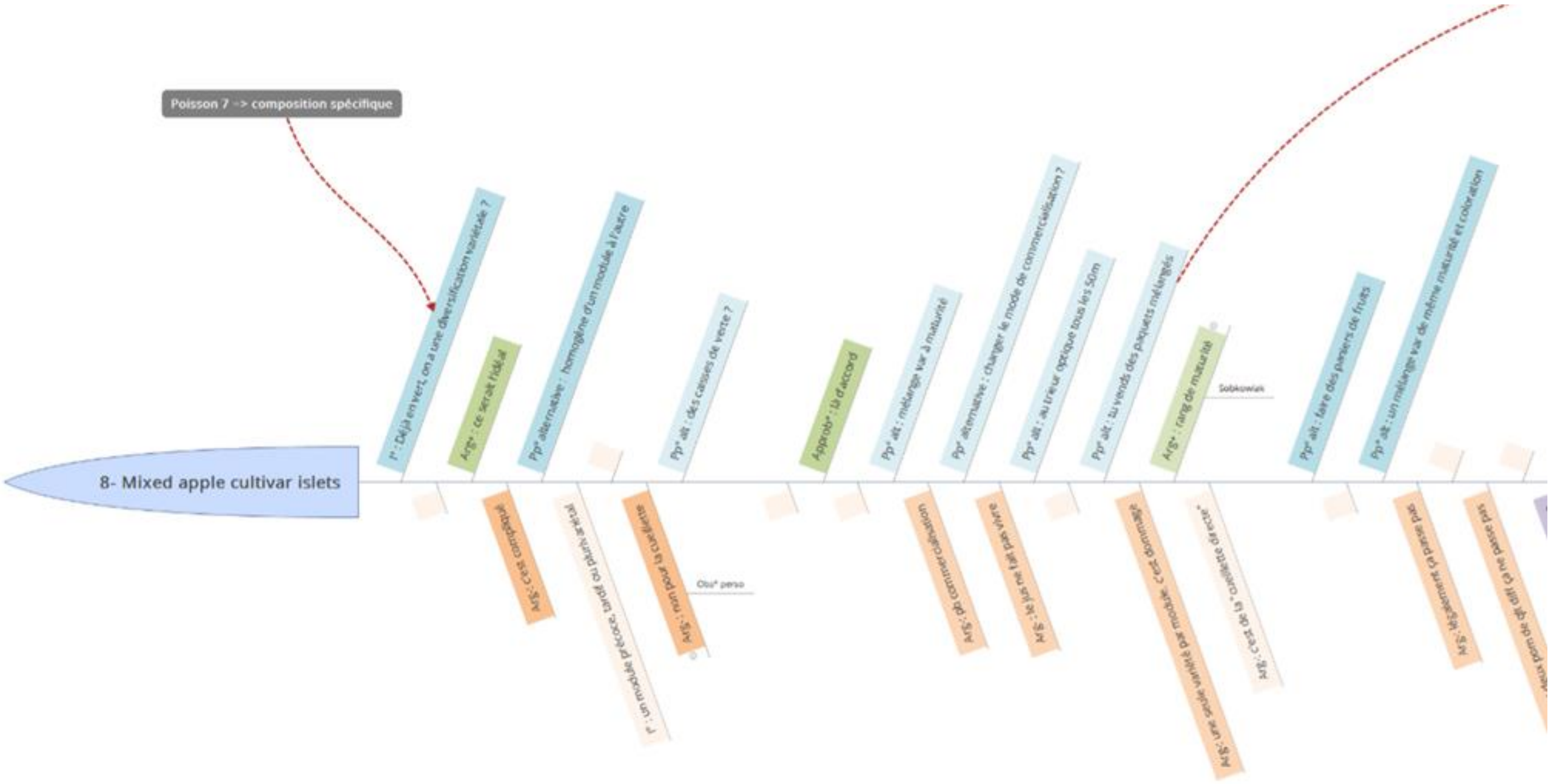


Figure 21 the eighth fish-idea of table 4, 'mixing cultivars into the islets' part 1

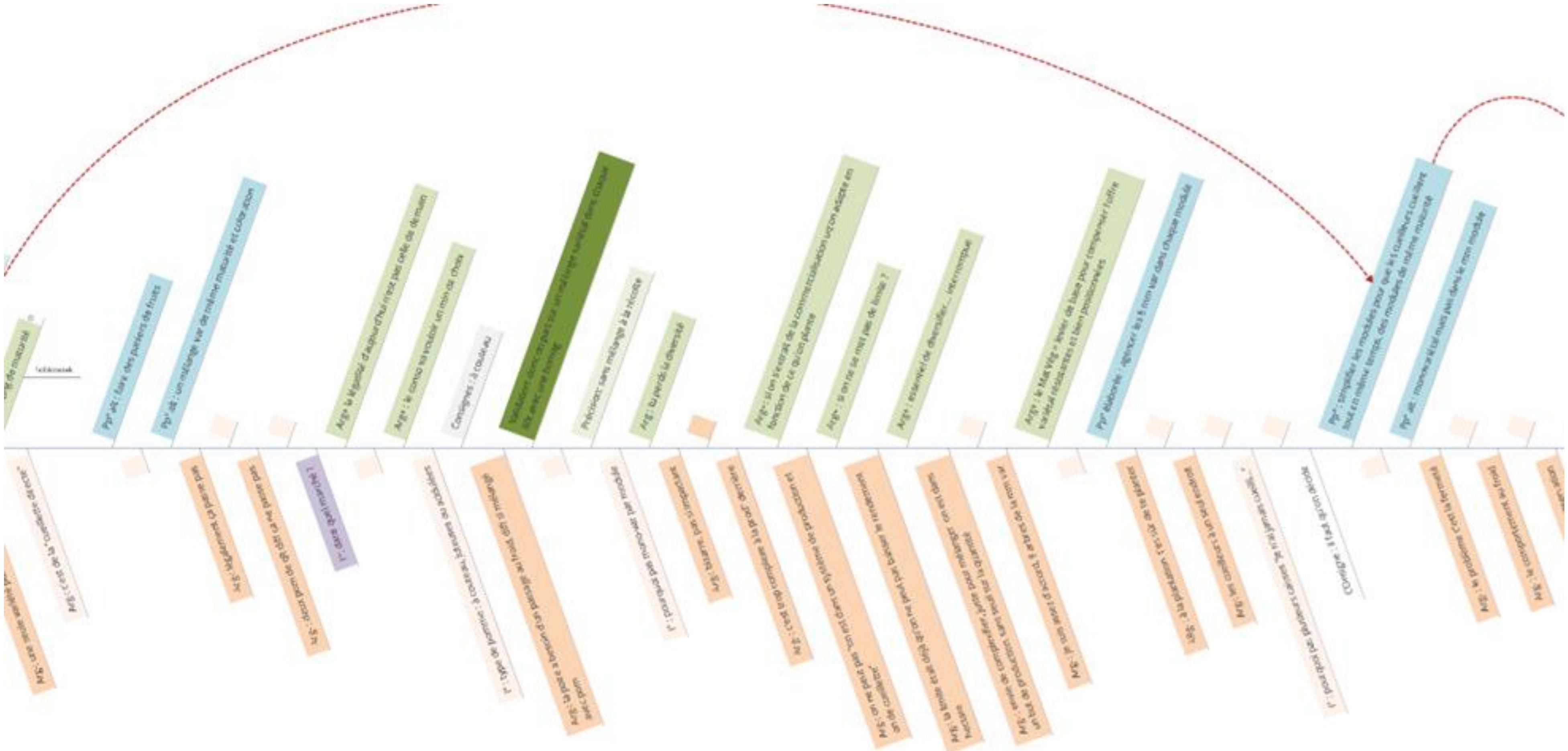


Figure 22 the eighth fish-idea of table 4, ‘mixing cultivars into the islets’ part 2

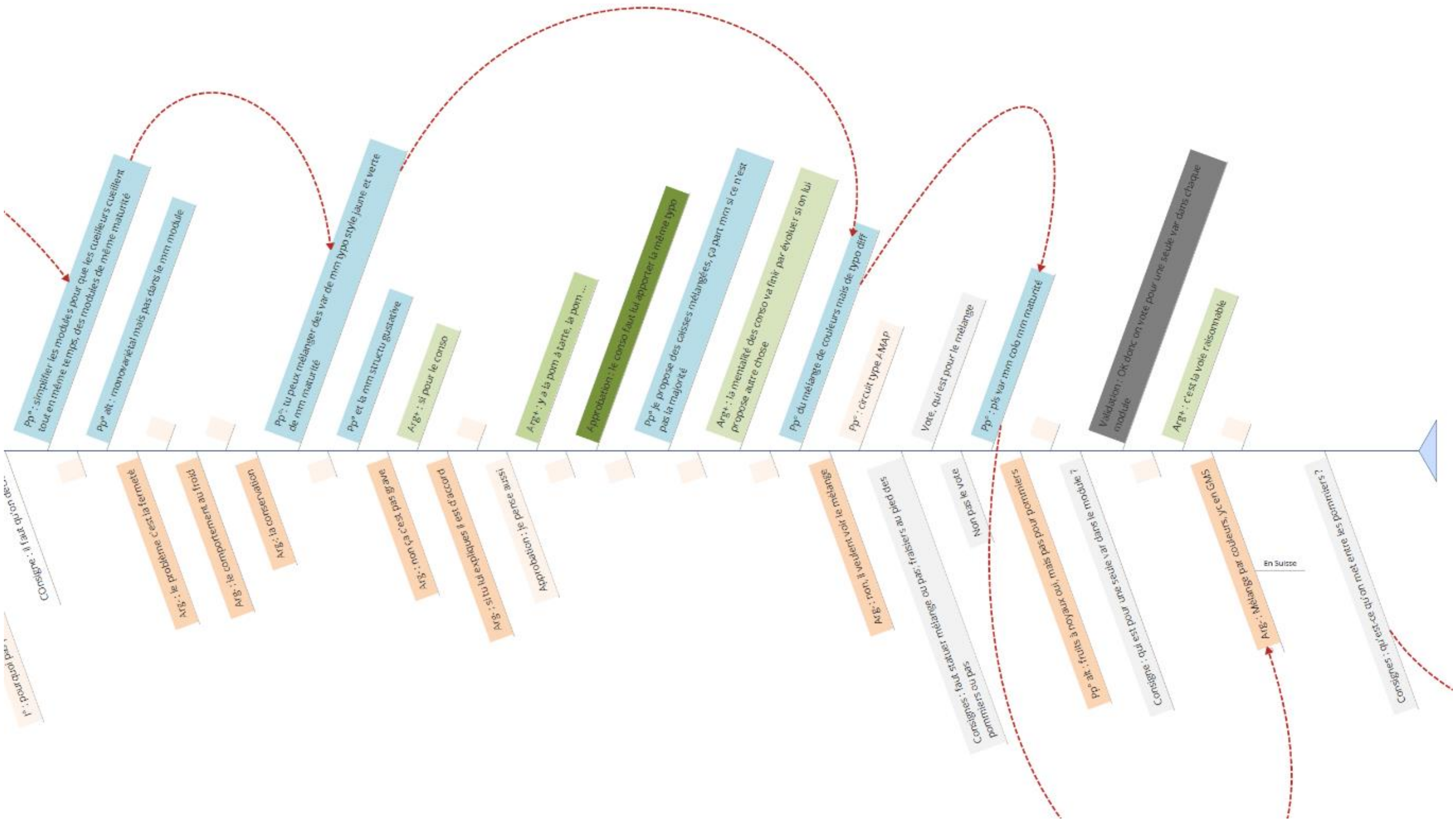


Figure 23 the eighth fish-idea of table 4, 'mixing cultivars into the islets' part 3

9- Companion plants

Facilitator brought the last fish with the question "Qu'est ce qu'on met entre les pommiers? (What do we put in between apple trees?)". The beginning of the discussion was mainly led by one participant, expert in biodiversity, whose proposals were not contradicted and therefore implemented on the Playmaïs© layout. The subject mobilized references as well and the critics that were made at the end of the discussion helped to specify and enrich ideas for instance on the management of the competition between fruit tree species and companion plants or the management of grasses. The work session tailed off with a return of considerations about productivity regarding competition among fruit trees and companion plants, when the last proposal of planting berries on the Playmaïs© layout was defined.

To conclude, this representation emphasis that fish have more or less fishbones, showing that some topics are more debated than others. Some ideas brought more references (see sunlight funnel fish) whereas others focus on context elements (see straight rows fish).

Proposals have three kinds of sources: they can be new and disconnected from previous discussions, proposed as an alternative to a controverted proposal or enriched from a previous proposal. The speed of proposals to be accepted, i.e. transformed in Playmais© or noted on the paper board mainly depends on the number of positive supports and the power of the assertion (and maybe of the speaker). In addition, the logical way to support a proposal consisted in suggesting a new technical idea and consequently justifying it. However, many proposals that were accepted also come in response to an aforementioned and shared need, a vision of how the system should work.

We observed that ideas had different levels of disruption, for instance the circular shape was considered as lacking innovation because it was managed as rows, whereas the aleatory seeding showed lack of knowledge "on ne sait pas ce qu'on va avoir (we do not know what we will get)", experimenter, and therefore demonstrated a high level of disruption.

Finally, we decrypted the process of selection that leads to an idea being accepted or 'evaporated'. In fact, ideas were either rejected (e.g. the aleatory seeding), transformed (e.g. the forest like islets into the well of sunlight) or alternative (e.g. the forest-like islets instead of the aleatory seeding).

Fish showed the important role of the intermediary object, the spatial layout, and facilitator to refocus on the discussion to picture ideas and progress (see fruit tree diversification fish).

Whereas timelines showed the succession of technical proposals topics, fish analyzed the succession of the different types of contributions, with the inclusion of the role facilitators have in discussion. In contrast to quantitative analysis, fish allow a finer qualitative approach to analyze interactions between participants contributions in building design solutions.

4. Discussion

This master thesis is part of the research about co-design in agroecology. Particularly, it was focused on the design of a pesticide-free fruit production prototype relying on ecosystem services to be further experimented. We do not have the hindsight necessary to compare with other experiences on the subject because very few references are available (but see Lefèvre, 2013; Malézieux, 2012; Berthet et al, 2015). Particularly, experiences and bibliography on expert-based co-design of innovative on-station fruit production systems do not exist. This work was therefore exploratory, and interdisciplinary, especially with a social perspective in the use for agronomy (none of us were sociologists) to improve agroecosystem design and management.

This was ambitious work since it was new. The working perimeter had to be defined and we did not expect the wealth of workshop exchanges. The design process *per se* and the analysis required a variety of supports to test proposals and display the results e.g. drawings, 'Playmaïs©' design, 3D modelling, and fish ideas construction. But the most challenging work was to integrate all data from the workshop, i.e. four times one and a half hour of exchanges, including the analysis of individual contributions and the categorization of each statement in nature and type, to identify the knowledge brought by workshop participants and the knowledge produced during the workshops and/or the capacity of participants to integrate 'scattered' knowledge. The discussion will first focus on the overall process of prototyping then on the main workshop itself to outline methodological learnings and propose improvements. Last, general considerations about knowledge sharing and knowledge production are discussed.

4.1. A long and complex overall design process

The overall process was long and complex: it started a year ago when the Gotheron team settled the objectives and the framework of their project to design a pesticide-free tree-based agroecosystem, and was not yet finished at the end of my internship. It relied on a bibliography step on ecosystem services in orchards, two multi-actors' workshops to propose innovative prototypes, and a succession of meetings gathering the Gotheron team to finalize a prototype.

Imagination vs realism

What we learned from the 'Verger Durable' workshop is firstly that designing an agroecosystem based on detailed levers from bibliography, reduce the range of options or creativity. Indeed, participants preferred to implement and discuss the levers we proposed rather than looking for new ones. Secondly, we asked the two tables of participants to work separately on categories of bio-aggressors (e.g., pests and diseases), showing incompatibilities between the two approaches since closed and open/aerated settings were proposed, respectively. This outlined the necessity first to take a step back on generic knowledge on ecological processes if we wanted to maximize the creativity of people, and secondly, either to have a global approach (i.e., to consider all bio-aggressors simultaneously) or to hierarchize the importance of the considered bio-aggressors before the workshop. The 2.0 workshop considered the Gotheron objectives and context as well as the same generic knowledge on ecological processes (but with minimum details) to co-design consistent agroecosystems. The idea was to look for an overall consistency of processes aiming at pest exclusion that we called 'realism'. Indeed, the exercise was in between imagination (participants having 'carte blanche' to design anything but maybe far from Gotheron expectations) and feasibility, which is a very selective process and therefore tends to exclude new proposals. We realized afterwards with participants and the team debriefings that this ambiguity in the objective of the exercise disturbed many participants and was probably amplified due to the limited time and the difficulty to set a clear context with components already stated by Gotheron e.g. surrounding for agroecological infrastructures were already discussed in Gotheron meetings but insufficiently elaborated to share with participants. Therefore, almost every table put around the production area, hedges which were probably unnecessary. In other words, the efficiency of the one hour and thirty minutes of prototyping could have been improved. The outputs of some tables were therefore closer to a general outline than a prototype ready to be planted.

On-station vs on-farm design

The complexity of the process was even more obvious after the 2.0 workshop when the Gotheron team did the exercise to draw their own vision of the prototype. Since the whole team was involved in the design process, the difficulty was to group multi-headed imaginary representations into one. One member said: "Ce n'était pas difficile de statuer la forme circulaire, mais je ne me rendais pas compte qu'il y avait autant de façons différentes de la faire. (It was not too difficult to decide on the circular shape [of the prototype] but I didn't realize there were so many ways to manage it". Indeed, designing agroecosystem for farmers is different from on-station design. Farmers have one representation for one agroecosystem whereas on-station design is multi-headed (e.g. Lefèvre, 2013). Designing on-station fruit tree systems requires satisfying all team members who will work daily on the experiment. On-station experimentation also have scientific and knowledge production objectives. Collective design was thus even longer here because "we do not know how to do it", therefore this lack of knowledge induced frequent switches between ideas association, processes, hypotheses and feasibility to design the final system. Decisions were either set from consensus or accepted by a majority, which required debates and time.

We wanted to co-design a prototype that would be environmentally sustainable and would answer the needs of fruit production stakeholders, which is why we decided to look at participative science. However, we knew the orchard will only be adapted to the Gotheron context and not be applicable on farms before fifteen years time. Therefore, the workshop was not participative but consultative by expert opinion. One question raised: What do experts get in return and what is the usability of the outputs of the tables for Gotheron? Firstly, participants may have changed their view on orchards: starting a design by processes, i.e. the pest suppression approach, relativize production objectives and/or imagine a scale of options. Secondly, the workshop may have shown the diversity of knowledge (e.g. scientific and empirical) to mobilize as well as already existing knowledge, and finally the advantage of a group event to gather these stakeholders together in order to produce new knowledge existed over a 90-minute period and was as useful for the workshop as for participants. Indeed, participants proved it when showing more enthusiasm for their exchanges than the outputs themselves.

Several ways to answer the objective

The approach was also manifold: there was neither a unique way nor a unique prototype to answer the Gotheron team's expectations. Indeed, the four tables proposed prototypes that fitted the initial objectives. Regarding the four outputs, we had three different fruit trees managements: in circles (tables 1 and 3), in evolving islets (table 2) and in 'V' shaped islets with biodiversity cores (table 4) (see Figures 5, 6, 7 and 8). Retrospectively, Gotheron hesitated at the beginning of the meetings after workshop 2.0, between a circular and a 'V' shaped islet which was considered as very innovative and which should be tested. More members wanted to start on a circular shape but Gotheron may test the 'V' shaped orchard on another module. What is also interesting here is that prototype 1 aws often mentioned during Gotheron meetings. When looking at the questionnaire, whereas prototype of table 1 satisfied every participant, the other tables had mixed feelings. In addition, tables 1 and 4 had both the highest number of proposals. Therefore, regarding both satisfaction of the prototypes and numbers of contributions, we can objectively explain the use of prototype 1 in Gotheron meetings because prototype 1 was the closest prototype to Gotheron objectives. However, the final Gotheron prototype included some elements of the four prototypes from the workshop, including the circular shape and the central pond from tables 1 and 3, the surrounding ring as an outside barrier and apricot trees from table 1, as well as the idea of a fruit hedge derived from table 3. Gotheron team still needs more meetings to choose companion plants and inter-rows management, but they now have the general outline and management of the agroecosystem.

Finally, we should not forget that participants did one-and-a-half-hour work sessions whereas Gotheron had around twenty hours meetings, in order to take decisions over 15 years. Therefore, because it was new, unframed and collectively managed, we should not underestimate the time necessary to develop it, i.e. to move back and forth between imagination and realism, to select the most appropriate proposals and to get consensus on them. The overall process allowed the objective to be reached to co-design an innovative agroecosystem based on expertise and ecological processes to find a consensus between production and ecological functioning.

4.2. Actors' contribution: multiple way to contribute, discuss ideas and co-design

As performed by Barcellini et al. (2015) with the adaptation of the ARAD approach, we used a fine-grained qualitative approach to capture the actual content of the discussions and the role of the participants in fostering participatory design processes.

From the questionnaire and records analysis, several levels could be considered in the discussion on the contributions and the limits of the 2.0 workshop that aimed to gather several actors to co-design an innovative on-station orchard. The organization of 4 tables –which is seldom the case in workshops- led to similarities being highlighted as well as general trends and some differences among tables to propose more generic learnings.

A diversity of professional activities influenced by personalities but showing several tendencies

Except from animators and the Gotheron team, types and nature of contributions (see Figure 16) were not substantially different regarding professional activities. Of course, all participants were experts on discussed topics but the personalities rather than the professional activity influenced the number of contributions. The nature of participants -constructive or more skeptical-, the familiarity with this type of workshop and their confidence and experience in designing ecological orchards without pesticides certainly influenced the rate of participation (see Figures 13 and 14).

It is therefore difficult to deduce a typology of professional activities suitable to designing agroecological fruit production systems. However, we can conclude that predefined experts e.g. key informants, biodiversity experts, showed efficiency in ideas they proposed or discussed; e.g. the biodiversity expert on table 4 proposed cypresses in between fruit trees for birds that do not nest in cavities. Indeed, cypresses would bring a diversity to the orchard of birds which would regulate insects and which cannot be attracted by bird nesting boxes. Barcellini et al. (2015) also promoted to develop an extended core of experts to enlarge co-design processes.

Moreover, the high rate of farmers' participation (see Figure 13) may attest to the fact that they feel solicited for their knowledge of perennial agroecosystems and that they feel implicated because they are the final users of the knowledge that may be produced with these innovative agroecosystems. Therefore, farmers' presence is essential in expert-based workshops.

The presence of trainers asks the question of their low participation but we should be careful about drawing quick conclusions keeping a long term perspective, i.e. if they did not talk, it is probably because they felt inadequate to the proposed exercise. Indeed, on a long-term perspective, teachers and trainers are important in co-design to spread collective knowledge created in and after workshops. In other words, they have an important part in moving from specific to generic knowledge.

Analysis of the records showed that participants interact through various types of contributions regardless of their professional activity, i.e. there was no 'exclusivity': key informants are not the only participant to explain observation through processes, nor researchers to support proposals or observation with references. The same was even observed on the nature of the references. Of course, farmers usually referred to personal experience, whereas advisors referred to observations on the farms they advise. Researchers and experimenters both referred to own experiments and outside experiments. However, again there were no exclusivity, especially about scientific papers, which were seldomly raised and could be mentioned by other professional categories than researchers.

Our results suggest thereby that establishing the profile of participants with their professional activity only is probably not relevant. Understanding participants contribution and their roles is however essential to build an efficient participatory process (Barcellini et al. 2015), which requires to consider participants behavior and their capacity to adapt to the group.

Unexpected flexibility of participants to regulate debate and build a group 'identity'

We showed that many participants contributed in various manners to the co-design process, including regulation of the debate and contribution to the group 'identity', which echo back to the roles they took in group discussions.

We observed that participants often needed to reformulate to obtain agreement, to appropriate themselves the terms or to state components, e.g. the 'well of sunlight' found in permaculture principles was reformulated in 'funnel of sunlight' at table 4. One hypothesis based on this observation is that reformulations are necessary to participants to create their vocabulary, a group vocabulary helping to create the group cohesion and a working atmosphere (Toffolini, 2016).

Moreover, in contrast with the objectives of facilitation we had, all professional categories, even organizers proposed technical proposals and contributed to facilitate discussions, e.g. two participants on tables 1 and 2 took on a role of facilitator spontaneously (deducted from their personal high rate of validation). Participants could have a role of motivating and reassuring the group: "on a des connaissances, on n'est pas complètement démuni (we have knowledge, we are not completely lost)".

Finally, participants were flexible in the role they took according to the composition of the group, i.e. the capacity to adapt and change position when the group discussion stagnated. For example, at the beginning of the work session, the group at table 3 was very slow to propose ideas and an experimenter who was always coming back to the objectives of the exercise changed his mind set and ended up being the participant proposing the most technical proposals.

According to Barcellini et al (2015), roles participants take during a group discussion are either conceptual, functional or operational. Here, hypothetically, the researchers could be considered as more conceptual, the key informants who generally gave the processes could be considered as functional, and farmers who are linked daily to concrete measures would be operational.

Implicit and explicit contributions

As mentioned in the methods and described in detail below, we used and propose an original categorization of the contributions. Results of our categorization show that participants quantitatively contributed the most with technical proposals, queries, positive arguments and validations. This may attest to the need for ideas to be explored with queries, approved by the other participants and supported with arguments. In contrast, detailed references and processes were little-mentioned. Lack of references may be explained through (i) references are scarce and (ii) the fact that there was no need to support justifications with references to convince or induce reactions to other members of the table. Participants usually did not speak in terms of processes -except key informants- and the processes mobilized mostly referred to ecological processes to regulates pests and diseases. This could be explained by (i) a lack of knowledge on ecological mechanisms or (ii) the group dynamic which impeded participants speaking in terms of mechanism of action.

An interesting aspect of this work as well is that it allowed revealing implicit contributions to be shown. Indeed, we demonstrated disconnections between what participants felt they contributed and what we analyzed, which are in overall underestimated. This suggests that participants used implicit knowledge they were not aware of. What fields of expertise were underestimated and why?

We had difficulty in analyzing contributions: audio recording may not be the best media, because (i) it omitted adjacent discussions, (ii) when transcribing records, it was hard to recognize eleven to twelve different voices and (iii) participants designing the spatial layout often used nonspecific terms e.g. “là”, “ici”, “ça” (there, here, that), resulting in disconnections between steps of construction and discussions.

For the questionnaire, we used the regular fields of expertise for the multiple-choice questions and we added a box that participants could complete if it did not fit in the existing categories. We did not get numerous ‘other’ fields of expertise which supports the idea that participants felt most of the categories matched with their subjective fields of expertise. When analyzing contributions and particularly the technical proposals, we developed a classification to embrace their diversity and maximize exclusivity between topics. We could not use the fields of expertise categorization (even if they are close) because most of the levers are multi-functional, e.g. wild mustard is competitive with weeds and repulsive for pests therefore having both functions of improving soil fertility and crop protection. Proposals were thus classified by components of the system, e.g. wild mustard is a companion plant which was included in biodiversity category. Therefore, we realized the non-matching between designing -the components- and the skills gathered. Consequently, our methodology allowed us to adapt our categories to our case study and was therefore original because the categorization approach is quite generic.

However, other methods exist such as the CK method (Appendix 17), developed by Hatchuel and Weil (2009, cited in Berthet, 2013). CK method, i.e. Concept-Knowledge, divides proposals into Concept, i.e. the undecidable proposals, partly unknown which need a conception; and Knowledge, i.e. proposals with a logical status (either true or false). The benefit of this method is to differentiate generic proposals (concepts) from applied proposals (knowledge) and to map the conception reasoning. Indeed “les connaissances permettent de faire émerger de nouveaux concepts et ces derniers entraînent l’expansion des connaissances (knowledge allows the emergence of new concepts which in turn favorizes knowledge expansion)” (Berthet, 2015, p.26). This methodology is very conceptual in contrast with the Gotheron team approach and need therefore to be clearly defined in upstream works if tested for other expert- based co-design workshops.

Biodiversity was a field of expertise particularly significant in this workshop: participants having the role of ‘biodiversity expert’ felt they used this field of expertise and really used it although other fields of expertise were generally felt as underused. Perhaps biodiversity was a more ‘successful’ field of expertise here because people more or less knew their role before coming to the workshop, e.g. the expert from LPO (Ligue de Protection des Oiseaux) explained at the beginning of the work session that she was not an orchard expert but she could help to improve biodiversity with agroecological infrastructures. In contrast, one explanation to the underused fields of expertise is that the exercise was presented with a pest-suppressive approach, therefore participants used more ‘applied’ knowledge on pest control, which is not very specific knowledge on those topics but is sufficient to propose diverse ideas.

Participants had mixed feelings about their perceived contributions on orchard management but what we can say from discussion findings is that almost all participants proposed solutions or discussed them implicitly. We invited mostly orchard experts who were all familiar with basic or advanced orchard management knowledge, therefore most of them had already thought of how to facilitate human labor in innovative orchards or were in contrast very skeptical about complexifying the agroecosystem.

Moreover, differences might be explained by the fact that real contributions only included technical proposals that are categorized in topics, which is not representative of the overall work session. Indeed, some participants could consider they contributed to genetic resources because they gave positive or negative arguments but didn't concretely propose solutions or new ideas. Therefore, further analyses on participants' contribution should favorize an analysis on overall contributions in contrast with an analysis focusing on only one type of contribution and maybe try to get more details from participants in the questionnaire or with post workshop inquiries.

Finally, we did not propose spatial organization here as a field of expertise of agronomy, but it could be applied to plant association as well, as the questionnaire showed participants felt they contributed regardless of the fact of not having the field of expertise 'plant association'. It makes us wonder if spatial design and plant association could not, in a relatively close future, be considered as a full field of expertise.

In fact, the results attest to the necessity to gather new skills with different fields of expertise and to produce new knowledge on spatial organization of the components within a complexified orchard.

4.3. A fruitful but perfectible framework

We did not expect the enthusiasm about the workshop, when looking at the rate of participation among our invitations -about 36 participants external to Gotheron came out of 73 invitations sent, which is almost 50% !- Most of the participants had dealings with Gotheron or are in partnership with the project, but we also had unfamiliar local participants. Therefore, we successfully gathered people sharing the same goal to collectively design a fruit tree agroecosystem towards sustainability. We organized the workshop over half a day to maximize participation -of farmers especially- and maximize timing for a work session. To ensure the best conditions to start the workshop, we presented them with the Gotheron context as well as the generic knowledge on ecological processes we gathered in a (long) introduction.

During this introduction, we tried several methods of animation, e.g. show of hands or the theatre scene; that complied with our aim to get away of the classical 'conformist' frame. Our wish to create a comfortable atmosphere was mostly welcomed by participants, especially the theatre scene that made them laugh, e.g. one participant asked if we had filmed the scene. Globally, people were satisfied about the workshop. They appreciated the diversity of stakeholders and numerous participants noticed the wealth of the exchanges. However, they were very reserved about the time given to the work session, and gave ideas to improve its efficiency (see 4.4).

However, we probably missed out on something in the introduction concerning Gotheron: we may not have sufficiently explained the experimental (and not only productive) aim of the system, which would not give a system directly transposable to farmers. This was sometimes misunderstood, especially by people unfamiliar with Gotheron; on table 4, one farmer said “le but du jeu c’est de faire un truc qui ne soit pas trop galère pour nous mais qui le soit pour les ravageurs (the aim is to do something manageable for us and tough for pests)” to which the key informant explained that the system would not be directly transposable for farmers, therefore leading to “Ok, ok ça change un peu l’optique quoi. (Ok that changes the perspective)”.

Numerous participants had mixed feelings about the prototypes. The causes of non-satisfaction might be related to the way the layout was built because one or two participants monopolized the discussion, sometimes ideas were not appealing or the consensus was not interesting and therefore participants felt the prototype did not suit them. This partly sends back to ways of facilitation.

Facilitation and directives aimed to create a similar framework among tables to analyze data and provide generic considerations. This implied that tables shared a common basis, had the same methods of facilitation and clear directives. Here, we noticed that some instructions were unclear because discussed again in groups e.g. the recurring objective of production, or the need to discuss on sustainability concept as described in Barcellini et al (2015); and differences in methods of facilitation: one facilitator gave more freedom to discussions to allow points to be reasoned through, whereas another facilitator intervened frequently in order to keep participants focused on Gotheron objectives and to ask them to back up their statements.

In addition, the members of Gotheron team had their own view about the constraints and the fields open for design, which is why they proposed to group the context elements in a ‘table of contents’, with empty boxes to fill-in for the fields open to design. However, this table was probably imprecise to many participants -and perhaps the facilitators, and coupled with different interpretations by Gotheron members, thus partly explains variations in frameworks and therefore the discussion content.

One way of managing a work session is not necessarily better than another, however here the table who displayed the highest rate of satisfaction among participants, (see number of proposals and satisfaction of participants) was particularly effective on facilitation: the couple of facilitators and the key informant were experienced enough to get straight into the subject, and comfortable enough to avoid pitfalls. In addition, we observed that a farmer on this table who oversaw the spatial layout, proposed more ideas and had more queries. This could be explained by he fact that he was in a constructive position which gave him the role to embody abstract ideas and motivate other members of the table to be as exhaustive as possible. However, it is difficult to say if a ‘successful’ work session is due to the participants or to the animation; it is most probably related to both.

If we come back to other aspects of the organization, we found limits in the supports we used: the spatial layout focused participants on design and less on the list of species but this aspect is probably coupled with a lack of knowledge. The trestle with the possible levers based on bibliography (see Appendix 5), was certainly underused by participants, and we only have hypotheses to explain this. We introduced the levers during the plenary session in two different ways, first with the theatre scene and secondly on a power point. On table 4 especially, the key informant referred four times to it. We can easily eliminate the hypothesis that we did not succeed in their introduction. Either the support was not easy to use, or the levers were not detailed enough or the spatial layout overtook the attention of the participants or participants were not familiar with the process, or, in groups they talk very little in terms of processes. What we can say is that the trestle was not necessary in this form.

4.4. Learnings for future agroecological design activities

Participants and fields of expertise

Choosing the fields of expertise of the participants is very important to compose groups, in terms of the knowledge to bring in to design a balanced and documented agroecosystem. Particularly, regarding the question about spatial organization and plant association expertise in agronomy, we wonder if integrating specialists of land- and farm-scaping, geography and orchard design -which doesn't exist yet- could be useful to gather permaculture principles, ancient practices and other knowledge adapted through ergonomic aspects, landscaping and geographic design.

Another point to consider about the personality of participants and their capacity to be constructive, which is not always the case in co-design from expertise. The fact that we knew almost all the participants shows therefore the importance of partnerships to gather people aiming towards the same objective, here to design a sustainable orchard management relying on bioregulation.

One suggestion would be to set tables per profiles to maximize exchanges but we would lose the value of the diversity and complementarity of stakeholders and the opportunity thinking 'out of the box'. Another suggestion would be to put participants in sub-topics e.g. a table focusing on cultivars, but we would lose the round trips between all topics and the comprehensive approach which crucial to designing a consistent agroecosystem, as well as there will be the difficulty of collating the results.

Regarding the role participants took to facilitate discussion and because experts in biodiversity claimed it gave them the legitimacy to be the 'voice of the biodiversity', one suggestion to improve co-design methodology from experts' opinion could be to give to each participant a specific role as a 'role play', to give him the 'legitimacy' to talk. The risk is that the exercise become more artificial, and that participants would be conditioned. In addition to the role given, to come back to the example of table 1, the farmer overseeing the spatial layout, felt very involved into the role to embody abstract ideas and motivated him to ask questions to precise ideas in the aim to traduce them on the spatial layout. Therefore, giving roles or missions to participants of a workshop could motivate them to feel invested and highly useful to the collective contribution. This experience could be coupled with an analysis based on the categorization of Barcellini et al (2015) to see the different conceptual, functional and operational roles the participants take.

Trained facilitators are important; the difficulty is to find a balance between a 'naïve' socio-technical knowledge of the facilitator, which allows him to make participants explain their ideas, and a good knowledge of the components to set to avoid pitfalls, e.g. seen on table 1. In addition, key informants are also important regarding framework flexibility, constraints and objectives (Gotheron participants in our case study). And of course, clear frame, objectives and supporting information (e.g. the table of components in our case study) are necessary to ease the management of the work session and further analyses. Moreover, necessary time must be set aside to create a group atmosphere and integrate the frame and concepts to produce collective knowledge: directives as well as ideas should be presented and discussed. In addition, we found intermediary synthesis very interesting in the validation of ideas, because either queries or confirmations stimulate discussions again. Lastly, the starting topic of the discussion is decisive; in our case study, starting with spatial design, especially with tree alignment or not, was a provocative topic: according to a participant "ça contraint trop (it's much too restraining)", but it elicited considerations for productivity, mechanization and processing, which were discussed on three tables out of four. Indeed, these are important considerations to take into account when designing an agroecosystem but could be time consuming topics of discussion.

Dreamtime and real time

To make participants express their knowledge and creativity, we proposed different supports, drawings and gaming board for discussion. It did help but it was also insufficient. Since tables did not proceed from a white slate but from knowledge on ecological processes and Gotheron context and constraints, the tradeoff between creativity and realism was not optimal and the exercise proposed was certainly too short compared to the scale of the task. One great recommendation for further workshops is to make a clear separation between the creative time to encourage new ideas maybe out of the box, which is the divergent part, and making the prototype realistic by choosing reasonable options or adapting a priori non-appropriate ideas, which is the convergent part of the exercise (see learning circle in Appendix 18, from Wilson and Morren, 1990). Either it could be done in a single but entire day, with a break in the middle, or it could be divided into two or three workshops spread over two or three weeks. The benefit of separating workshops over several days is that participants and organizers have the time to look for expertise that is lacking and to check references; but the disadvantage is that participants are not always available for the three meetings.

Information sharing

Regarding the support improvements, one participant asked for the documents e.g. the trestle of levers, so that he could better integrate the information. However, when sending documents before the workshop, the risk is that participants who 'forgot their homework' could feel uncomfortable. Therefore, when very little information is sent, participants are on an equal footing.

As we said above, records are not the best support to analyze the construction of ideas as there is a loss of meaning between living a discussion and reading it. Therefore, consistent analysis needs new supports especially when the intermediary object is of little visual value as a 'playing' board. Indeed, keeping visual tracks of the process in order to render its dynamism, is optimal.

4.5. Knowledge building process

Results are especially innovative regarding construction of the ideas. On the timelines, we showed similarities in the way to address topics between table 1 and 3, which also have similar outputs. Timelines showed the diversity of proposals that were made which we could not be recover on the spatial layout, e.g. nasturtium *Tropaeoleum majus* proposed as a trap plant for aphids on table 1 was not mentioned by participants or facilitators and therefore not written on the rapporteur's report nor on the spatial layout of the prototype. This could be improved by finding a way to show approved proposals but here timelines are more schematic because some information is lacking, for instance the sequence of technical proposals with arguments, references, processes, validations and queries. The best way we found to appreciate this information was the fish.

What we learned from fish is firstly that there are neutral contributions, e.g. process, precision, questions concerning explanations given, validation, precisions) that we could not put either on top of or below the back bone. Secondly, some fish were longer than others: some topics led to debate e.g. mixing cultivars, whereas some ideas were rapidly agreed upon and put on the spatial layout. Some ideas mobilized references e.g. forest-like islets and companion plants, while other fish mobilized elements of context, e.g. circling rows.

Fish could however be improved: they could be more readable because of the size and diagonal writing. Boundaries for ideas could be clearer because there were many round trips between ideas in the discussion. Finally, neutral contributions are not well represented, since they are either above or below the back bone which is a risk for misinterpretation. However, they do lead to opportunities to document and analyze dynamic processes such as co-design from agroecological processes. Moreover, instead of doing the post-analysis of the construction of ideas with the risk of losing information, fish could be used during the worksession. The rapporteur or the participants could have 'empty fish' supports to fill each time they start a new idea, which would help visibility to follow ideas individually, to deeper explanations, to keep records of rejected ideas and finally to see what topics remain to be discussed before the end of the worksession.

Other unexpected results are emphasized by the analyses of the contribution sequences and namely the order of technical proposals that may appear before or after the argumentation of an idea, and motivated by different reasons: a new idea, an alternative from a trade-off or an evolution from a 'raw' proposal. Fish gave clues to understand which ideas evaporated and what do they become. In fact, they did not really evaporate, but were either transformed (evolved proposals) e.g. forest-like islets into sunlight funnel islets, bypassed (alternative proposals), e.g. changing commercialization to allow mixing cultivars on islets; or merely rejected, e.g. aleatory seeding.

By analyzing contribution as far as ideas are concerned, we can draw several conclusions. Ideas were often built collectively, with participants successively supporting previous technical proposals, negative arguments and other critics contributing to specify ideas or create alternative or evolved ideas. Facilitation helped to revive, clarify, reformulate and concretize ideas and intermediary syntheses helped to summarize but also possibly risked scattering topics because of the numerous questions raised. The spatial layout, had at first only the role to stabilize consensus ideas, but as an intermediary object, it actually helped to ‘complete’ an idea and move to the next one, or to explain visually one proposal. Finally, fish analysis allowed to identify four types of trade-off: the productivity, the feasibility, the level of innovation and the time scale.

Conclusion

Gotheron’s general objectives were to create a fruit tree based agroecosystem maximizing functional biodiversity and especially relying on multi productive ecosystem services, with different functional zones. Such an approach is new in perennial temperate crops and this work is an initial step towards designing a first module and to thinking of further modules and design, e.g. fruit forest, biodiversity hotspots at the supraplot scale, and to considering the system more globally, including fruit valorization.

Methodological considerations from this case study and others could be used to improve the design process and agroecological co-design methodology. The main lessons reflect on: i) the participants, their complementarity and their willingness to produce and exchange knowledge in a defined context; ii) the need to take time either to settle the framework (context, aim, constraints), to capture and document proposals or to take ownership of the workshop output; iii) the importance of facilitation but conversely the possible flexibility of roles among participants creating a dynamic process; and iv) the difficulty to analyze knowledge building from scattered heterogeneous knowledge and experiences. Finally, the exchanges and knowledge produced in this workshop introduced a basis for a solid partnership with participants and the creation of an informal web to gather and share accessible knowledge.

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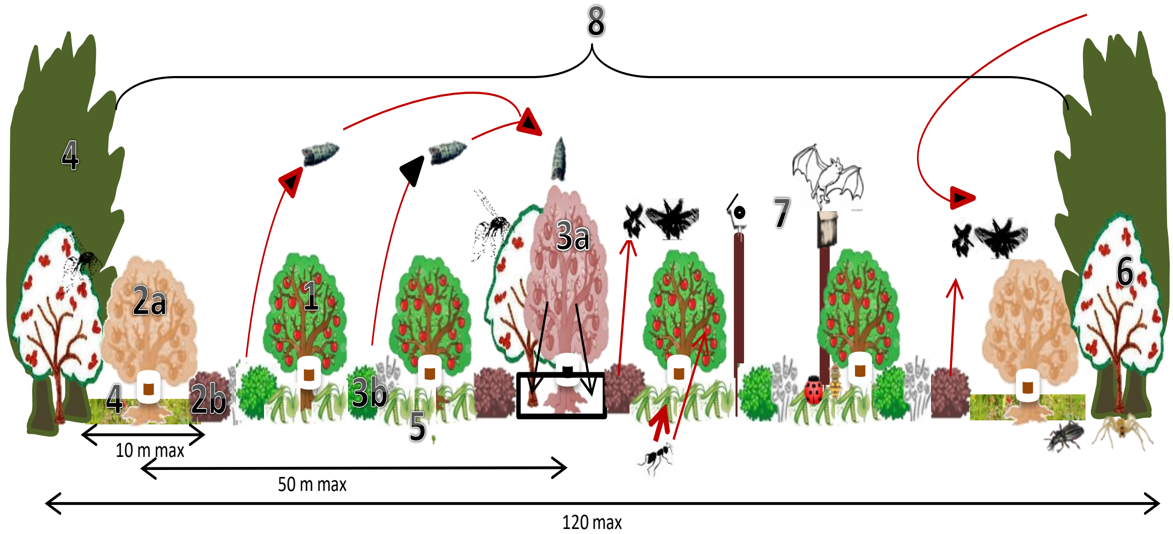
Appendices

Appendix 1: Pest suppressive pre-prototype (Rosy Apple Aphid & Codling Moth)

Pré-prototype de verger suppresseur de ravageurs: exemple avec le puceron cendré du pommier (*Dysaphis plantaginea*) et le carpocapse (*Cydia pomonella*).



1: Caractéristiques des pommiers
- Mélange variétés peu sensibles/résistantes puceron cendré et peu sensibles carpocapse
- Ecorce lisse et bandes carton alvéolé pour le piégeage des larves de carpocapse entre G1 et G2, G2 et G3 et diapausantes. Abris à araignées tout l'hiver.
- Conduite de l'arbre: centrifuge, nombreuses ramifications, faible vigueur.

2: Push-pull puceron
A – Pull: pommiers pièges résistants (ex: Florina) derrière la haie et tout le tour
B – Push: Plantes répulsives (**détournement des fourmis**), semis dense.

3: Push-pull carpocapse
A – Pull: Pommiers sensibles au carpocapse; mélange de pommiers à maturité plus précoce que les pommiers principaux et à maturité tardives; fruits et bandes piège de carton mis dans l'augmentorium. Arbres tous les 50m.
B – Push: plante répulsive, semis dense, loin du pommier piège.

4: Haie double strate à maximum 120 m des pommiers et zone non cultivée en bordure de 10 m. **Conservation des ennemis naturels et effet barrière.**

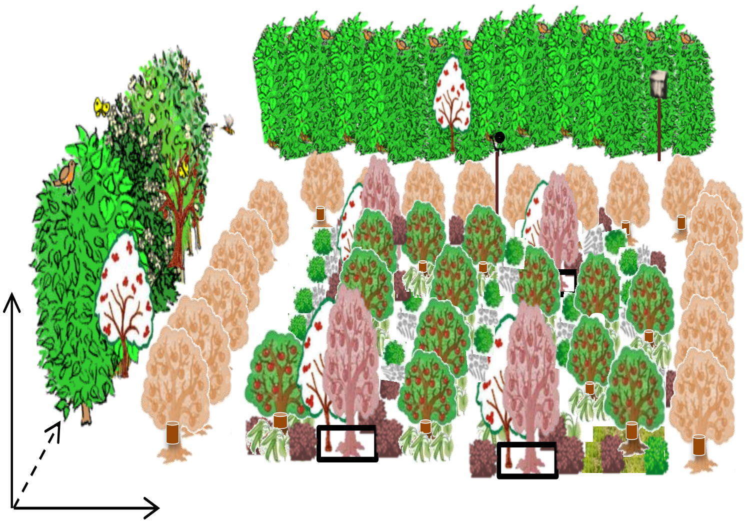
5: Plantes à pucerons (proies alternatives) au pied des pommiers en fleurs de Mars (ou avant) à l'automne. **Conservation des ennemis naturels et détournement des fourmis**

6: Hôte des parasitoïdes du puceron et du carpocapse dans la haie et le verger (Sorbier des oiseleurs, Jacinthe des bois, Aubépine, Apiacées,…). **Conservation des ennemis naturels.**

7: Nichoirs à mésanges (6 couples/ha minimum) et chauves-souris, point d'eau à proximité. **Conservation des ennemis naturels.**

8: **Effet dilution.**

Echelle supra parcellaire (suggestion de présentation):



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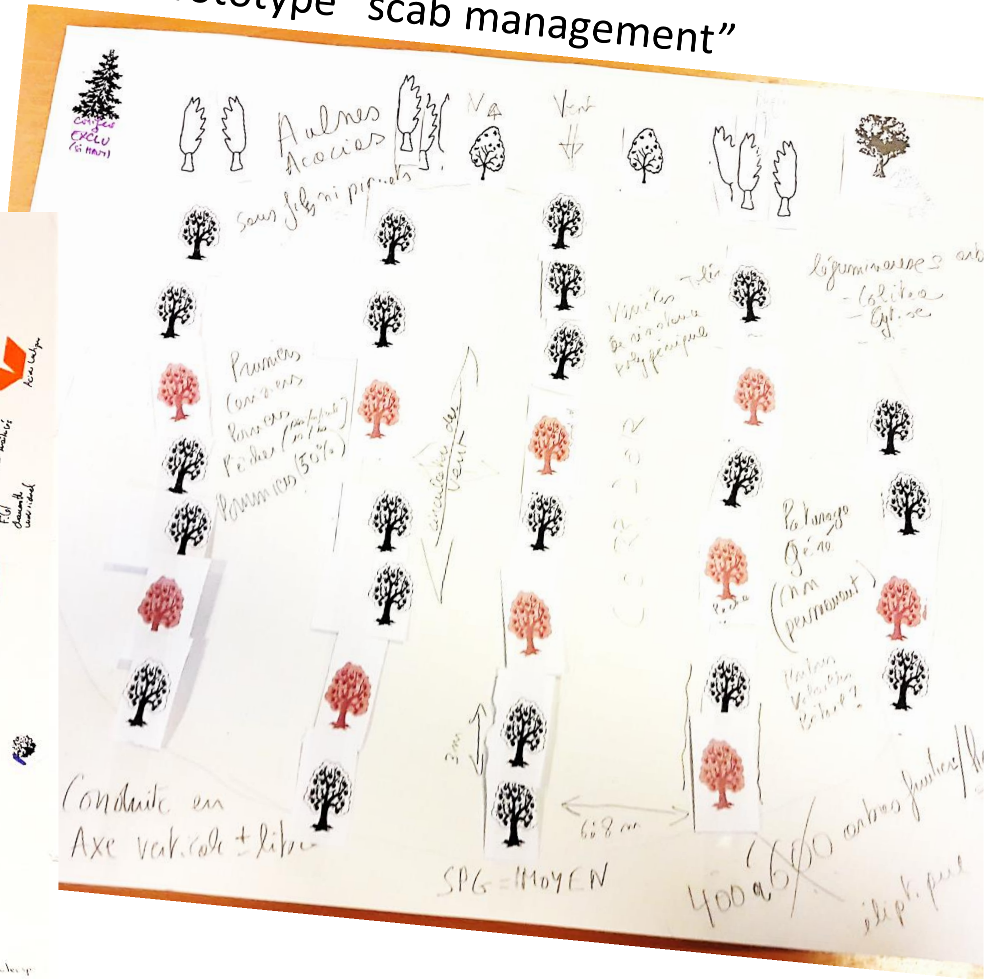
Appendix 2: Prototypes from Verger Durable workshop

Prototype “pest management”

Prototype “scab management”



Appendix 3: Workshop 2.0 hypotheses regarding professional activity and types of contributions

Catégories	**Contribution(s)** **type, nature des connaissances et objets agronomiques**	**Contre-contribution**	**Source**
Agriculteurs	-Expérience empirique : observations sur l'efficacité de certains leviers, -Créativité : nouvelles idées de leviers (qu'ils ont ou auraient aimées tester chez eux) -Conditions de validité d'un levier e.g. contraintes associées aux conditions pédoclimatiques et aux réalité de la production commerciale	-trop dans le conformisme/verrouillé/ -Peut ne pas laisser de place à l'incertitude sur l'efficacité d'un levier (pas de prise de risque)	-issue de leur propre expérience/connaissances -issue de leur entourage de références techniques (littérature techniques, conseils techniciens)
Techniciens-conseillers	-comme la catégorie agri mais avec une vue d'ensemble de ce qui se passe chez les agriculteurs (des observations répétées) -des connaissances plus objectives	-peur de se décrédibiliser auprès de ces agriculteurs s'ils leur présentent ces idées trop en rupture -peu de prise de risques	vu chez plusieurs agri veille technique (références et résultats expé)
Techniciens-expérimentateurs	Connaissances validées par l'expérimentation des idées exploratoires (des choses qu'ils aimeraient expérimenter)	-limités par la hiérarchie et les financeurs -Trop de conformisme	résultats de leur expérimentation veille scientifique et technique
Personnes ressources Biodiversité Mutli-espèces Matériel Végétal	-Connaissances spécifiques sur une composante du système -Observations expérimentales -Des leviers -Une compréhension des processus associés aux services écosystémiques	-pas proche des contraintes de production (du réalisme) - vision moins globale du système	synthèse de connaissances (observations) multiples littérature scientifique => Attention : ils auront peut-être plus de mal à citer leurs sources
Chercheurs	-Connaissances scientifiques / génériques -Une ouverture d'esprit pour des idées en rupture -Une cohérence globale	pas proche des contraintes de production (du réalisme)	littérature scientifique
Animateur de réseaux ? **=> A différencier des autres catégories**	-Connaissances des pratiques et réalité (enjeux) du terrain -Regard extérieur ni recherche ni production = "passeur de monde" -Point de vue socio-technique plutôt qu'uniquement technique		vu chez plusieurs agri veille technique (références et résultats expé) Synthèse de connaissances multiples Connaissances sociologiques
Formateurs (à vérifier s'ils ont vraiment un rôle attendu de formateur)	-considérations sur l'enseignement/la transmission à de jeunes agriculteurs -ils ont des contacts (ex. SFPPA) qui ont des attentes déjà réfléchies -Nous : vision long terme de leur importance parce que liée à l'enseignement	risque de ne pas trouver place/intérêt de leur présence dans l'atelier	allers-retours entre connaissances spécifiques et génériques et méthode de transmission
Equipe SAVAGE	-contraintes de l'expérimentation à l'INRA -Détails et raisons sur ce qui a déjà été défini (première colonne du tableau)	trop conforme à leurs anciennes pratiques	

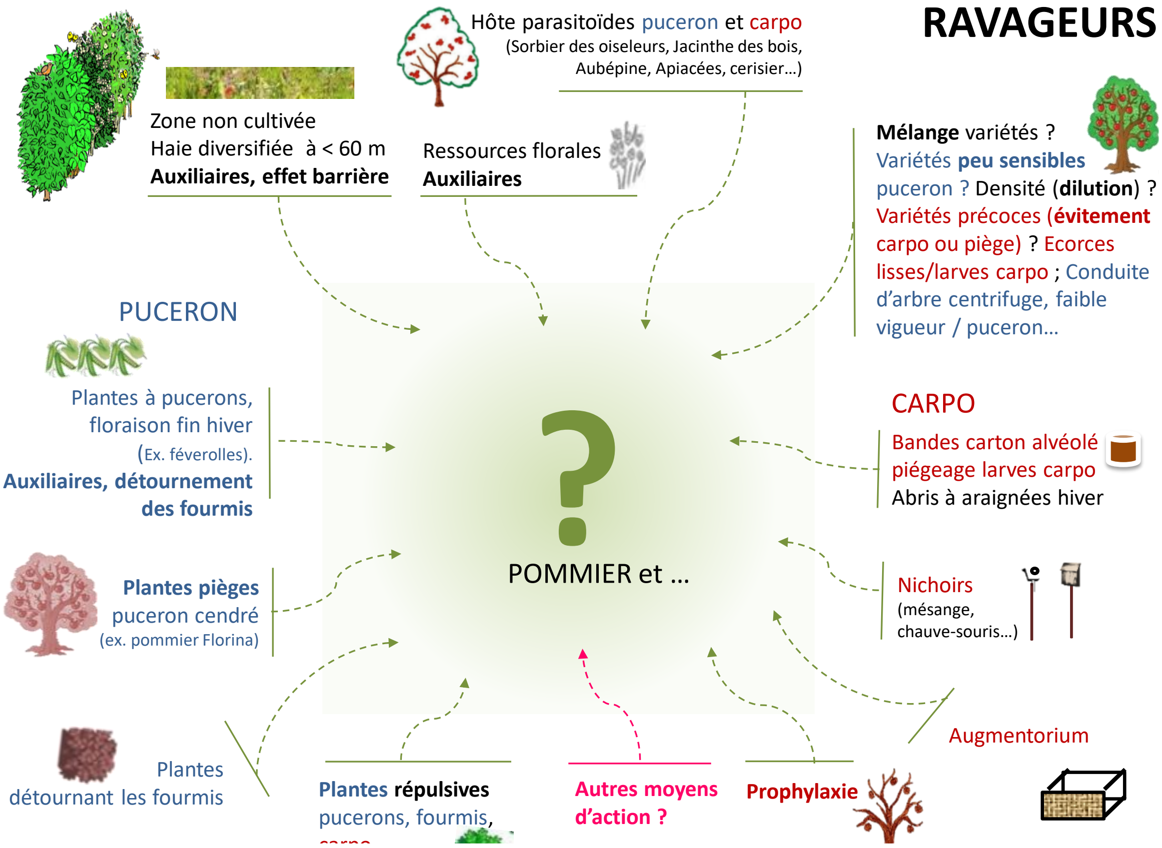
Appendix 4 : Workshop 2.0 detailed program

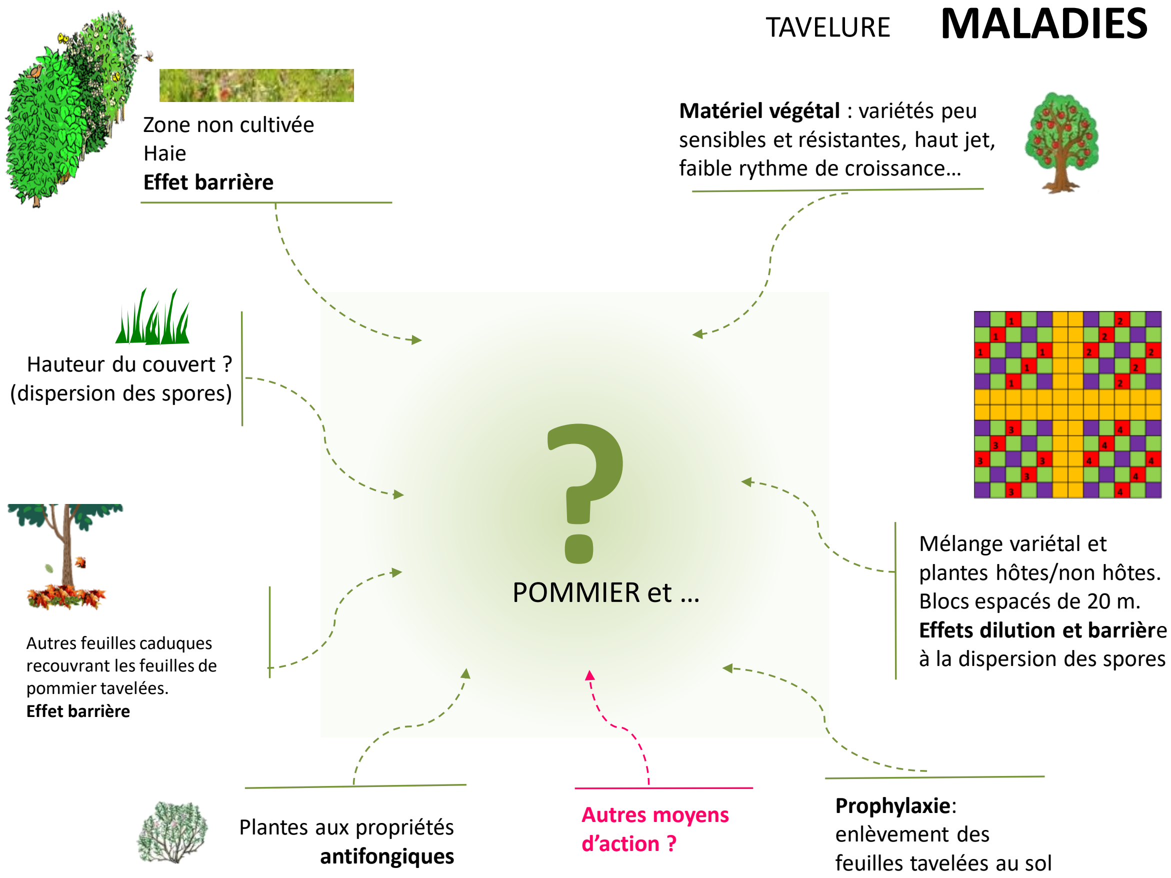
OBJECTIVE	PROGRAM PHASES	DESCRIPTION: HOW
Informal introduction, wait for last arrivals	Coffee welcoming and questionnaire distribution 15’	
	Welcoming speech in plenary 10’	Present Gotheron team, introduce general context
Atmosphere building: knowing who is who and everybody have skills to share. Catching expectations	Icebreaking phase : hand rising vote 10’	Who comes from Drôme? Who is farmer? Work on pip or pit fruits? Coming for the coffee? because you are daily confronted with estranged orchards? First word that come to your mind when we say ‘ Produce fruit differently ’
Put participants into Gotheron context	Z project presentation 10’	origins of the project, necessity to redesign the current orchard system
Catching personal expectations and what for they think they could contribute	Questionnaire presentation and filling part 1: profile and field of expertise 10’	
Atmosphere building Adopt processes and levers for work session	Theatre scene : pest regulation processes 5’	dynamic and disconcert
in order not to influence final design	Processes and levers presentation as supermarket items 15’	Split processes from any design present them more “seriously” and illustrated
Show animators,	Work session rules and installation around tables 15’	explain simply what we wait from them (table of components)

Appendix 4: Workshop 2.0 detailed program (following)

Deal with big queries, get a coherent system in terms of design and plant associations. Stay in to the subject and help everyone to express.	WORK SESSION Animators presentation + round table 5' and material supports presentation (mind map, trestle with levers/processes, model) 5' Intermediary summary (2x) (propositions, discussions, suppression) Last summary before restitution 1h30'	Animation loads are important (3/4 animators per table) +1 coordinator that turn around the tables
Optimize time and questions	Cross-restitutions : Table 1 with 3 and 2 with 4, restitution 2 by 2 35'	summaries are used for restitution
Catch subjective contributions, satisfaction/frustration of work session introduce a long term partnership	Back in plenary: in parallel filling part 2 of the questionnaire : perceived contributions Great witnesses restitution preparation Animators debriefing 5'	+ what lack to complete the prototype, positive or negative point of work shop, what do they take home and if they want to come back
have a outside view (compared to Gotheron)	Great witnesses synthesis	2 participants synthetize exchanges and express unexpected elements, concerns…
Introduction to the following events partnership collective knowledge building	Conclusion	Restitution morning in autumn Website platform?
Collect informal feedbacks, new information about participants, brings participants	Buffet	

Appendix 5: Workshop 2.0 ‘supermarket of levers’, insect and disease pests





Appendix 6: Professional activities and their belonging organisms per tables

Table 1		Table 2		Table 3		Table 4	
Category	Organism	Category	Organism	Category	Organism	Category	Organism
Experimenter/farme	GRAB	Farmer		Farmer		Farmer	
Farmer		Farmer		Trainer	Valentin Highschoo	Farmer	
Trainer	Valentin highschool	Farmer		Farm group leader	ADABIO	Advisor	Chambre Agricultur
Farm group leader	Agribio26	Trainer	educagri	Experimenter	TAB	Experimenter	CTIFL
Advisor	Chambre d'Agriculture 26	Farm group leader	Agribio07	Experimenter/ biodiversity expert	GRAB	Researcher/ great witness	Inra Montpellier
Researcher	CIRAD	Advisor	GRCETA	Researcher/ great witness	Inra Montpellier	Biodiversity expert	LPO
Tree nurseryman		Researcher	Inra Avignon	Experimenter/ biodiversity expert	CTIFL	Biodiversity expert	ITEPMAI
		Plant association expert	GRAB				
External participants	8	External participants	9	External participants	8	External participant	8
Gotheron team member		Gotheron team member		Gotheron team member		Researcher	Gotheron
Key informant	Gotheron	Key informant	Gotheron	Key informant	Gotheron	Gotheron team member	
Rapporteur	**Inra Avignon**	Rapporteur	**Gotheron**	Rapporteur	**Gotheron**	Rapporteur/ key informant	**Gotheron**
Facilitator	**Inra Avignon**	Facilitator	**Inra Avignon**	Facilitator	**Inra Avignon**	Facilitator	**Inra Avignon**
Logistic suport	*Gotheron*	Logistic suport	*Gotheron*	Logistic suport	*Avignon*	Logistic suport	*Gotheron*
Total	13		14		13		13

Appendix 7: Playmaïs© layouts

Appendix 8: Questionnaire of workshop 2.0

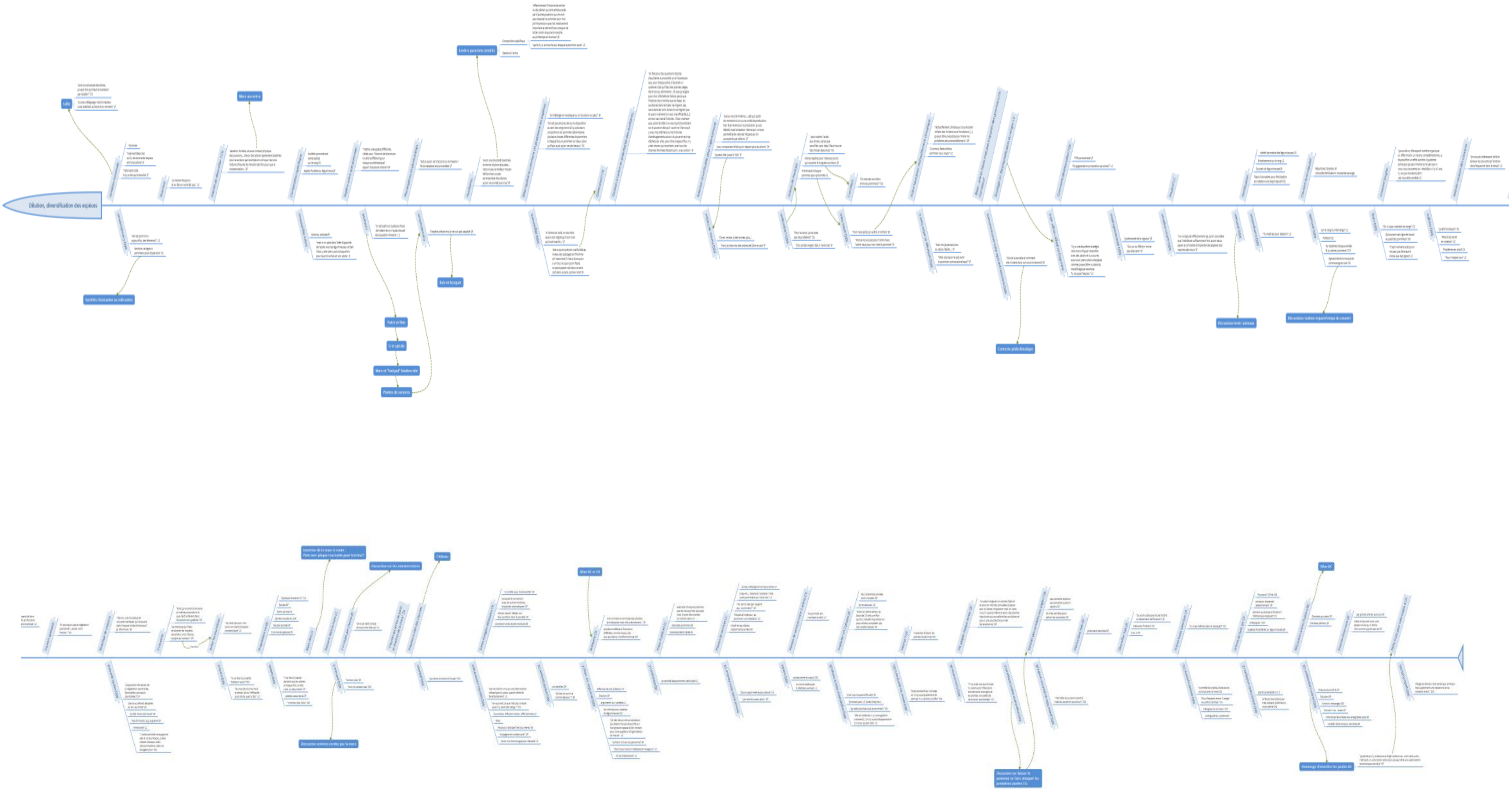
Part 1:

1. Quelle est votre activité professionnelle :
☐chercheur
☐conseiller
☐expérimentateur
☐agriculteur
☐formateur
☐animateur
☐technicien
☐étudiant ou autres: ……………………………
2. Pouvez-vous nous décrire votre métier actuel ?
3. Depuis combien de temps exercez-vous ce métier ?
4. Quel(s) est/sont les domaines pour le(s)quel(s) vous avez des expériences à partager:
☐le matériel végétal
☐la biodiversité
☐la gestion du sol
☐la protection des cultures
☐les associations de plantes
☐l'intégration d'animaux
☐la conduite des vergers
☐autres : …….
5. Quelles sont les raisons pour lesquelles vous avez accepté de venir participer à cet atelier ?
☐Le verger en rupture est votre quotidien et vous avez des expériences à échanger
☐Le verger en rupture vous intéresse et vous êtes à la recherche d'informations
☐Pour profiter du buffet !
☐Autres :
6. Quels sont les mots qui vous viennent à l'esprit quand on vous dit « produire des fruits autrement, sans pesticides » :
7. Êtes-vous familier avec ce type d'ateliers participatif ?
☐pas du tout
☐un peu
☐beaucoup
☐ passionnément
☐ à la folie

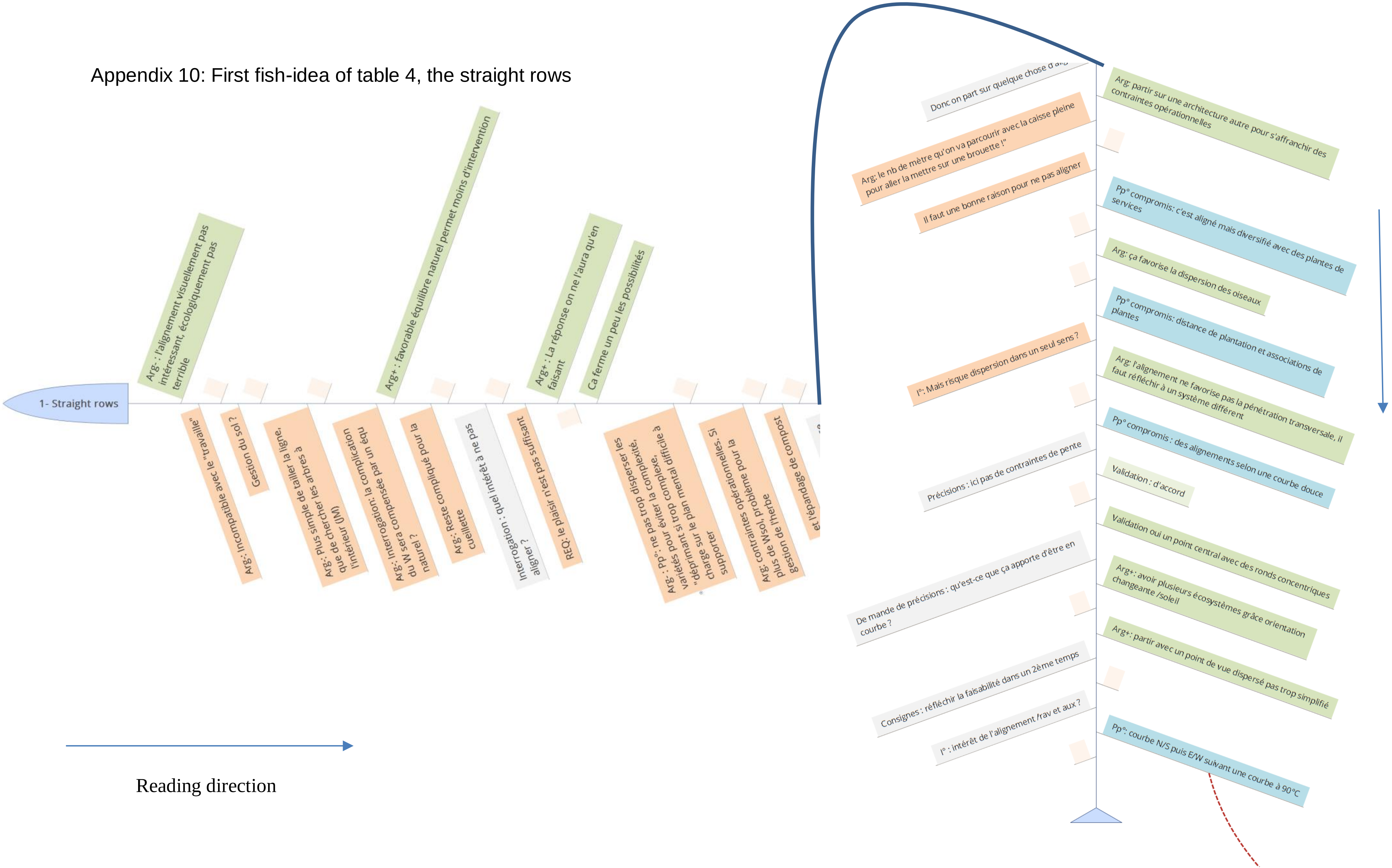
Part 2:

8. Que pensez-vous avoir apporté à l'atelier ?
9. Sur quelles dimensions êtes-vous surtout intervenu et comment ?
☐le matériel végétal, **comment :**
☐la biodiversité, **comment :**
☐la protection gestion du sol, **comment :**
☐la protection des cultures, **comment:**
☐les associations de plantes, **comment:**
☐la conduite des vergers, **comment :**
☐autres :
10. À chaud, êtes-vous satisfait du verger conçu à votre table ?
☐ oui ☐ non
En quoi pourrait-il être amélioré ?
11. a. Donner un point positif dans l'exercice de conception proposé en atelier ?
11. b. De même, donner un point à améliorer à ce type d'atelier ?
12. Qu'avez-vous appris pendant cette demi-journée ?
13. Si d'autres ateliers sont organisés, êtes-vous prêt à continuer l'aventure ?
☐ oui ☐ non
14. Souhaitez-vous être informé des suites du projet Z ?
☐ oui ☐ non
si oui laissez-nous votre contact :
Si vous avez d'autres commentaires à soumettre aux organisateurs :

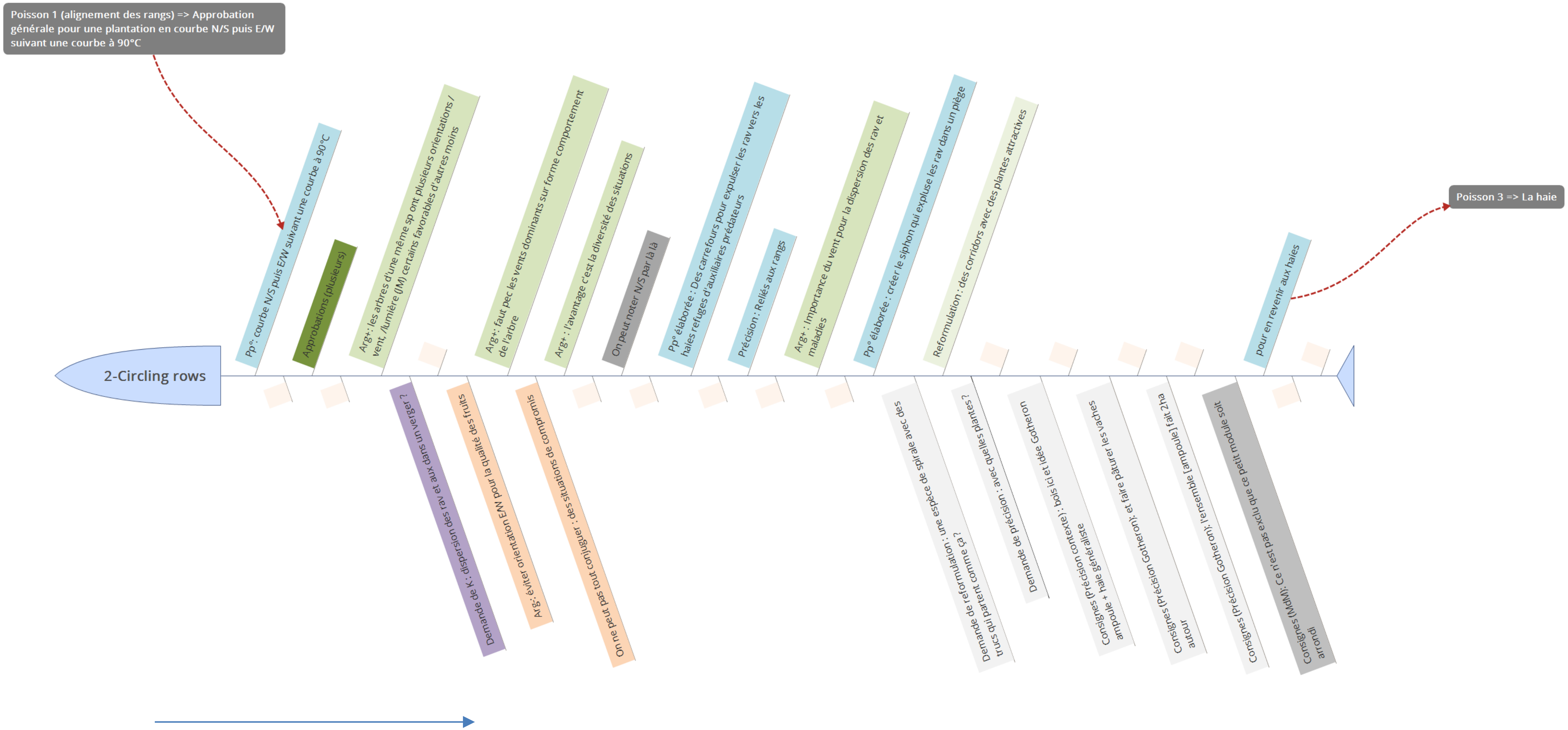
Appendix 9: The first fish try referred as the ‘the Moray’



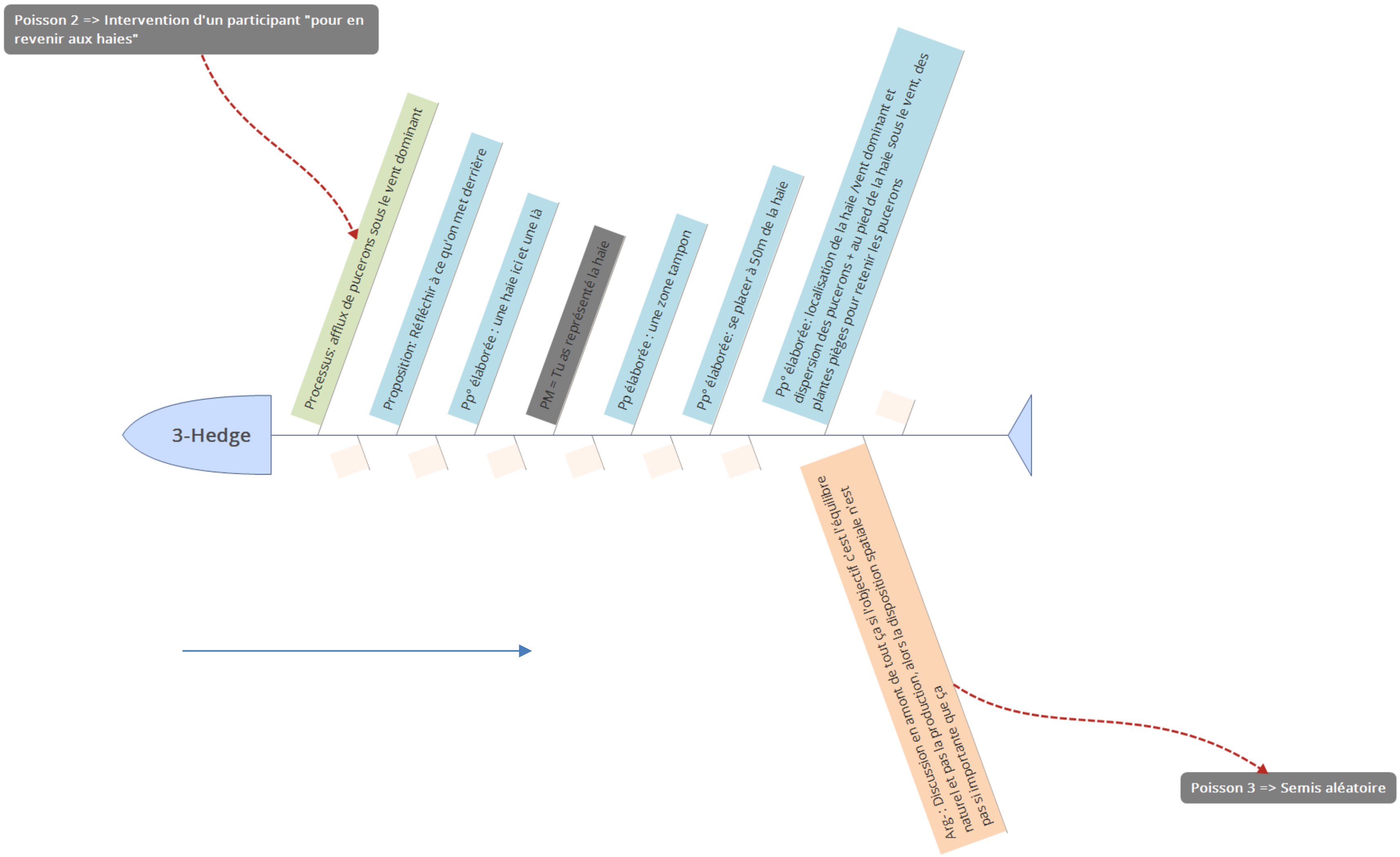
Appendix 10: First fish-idea of table 4, the straight rows



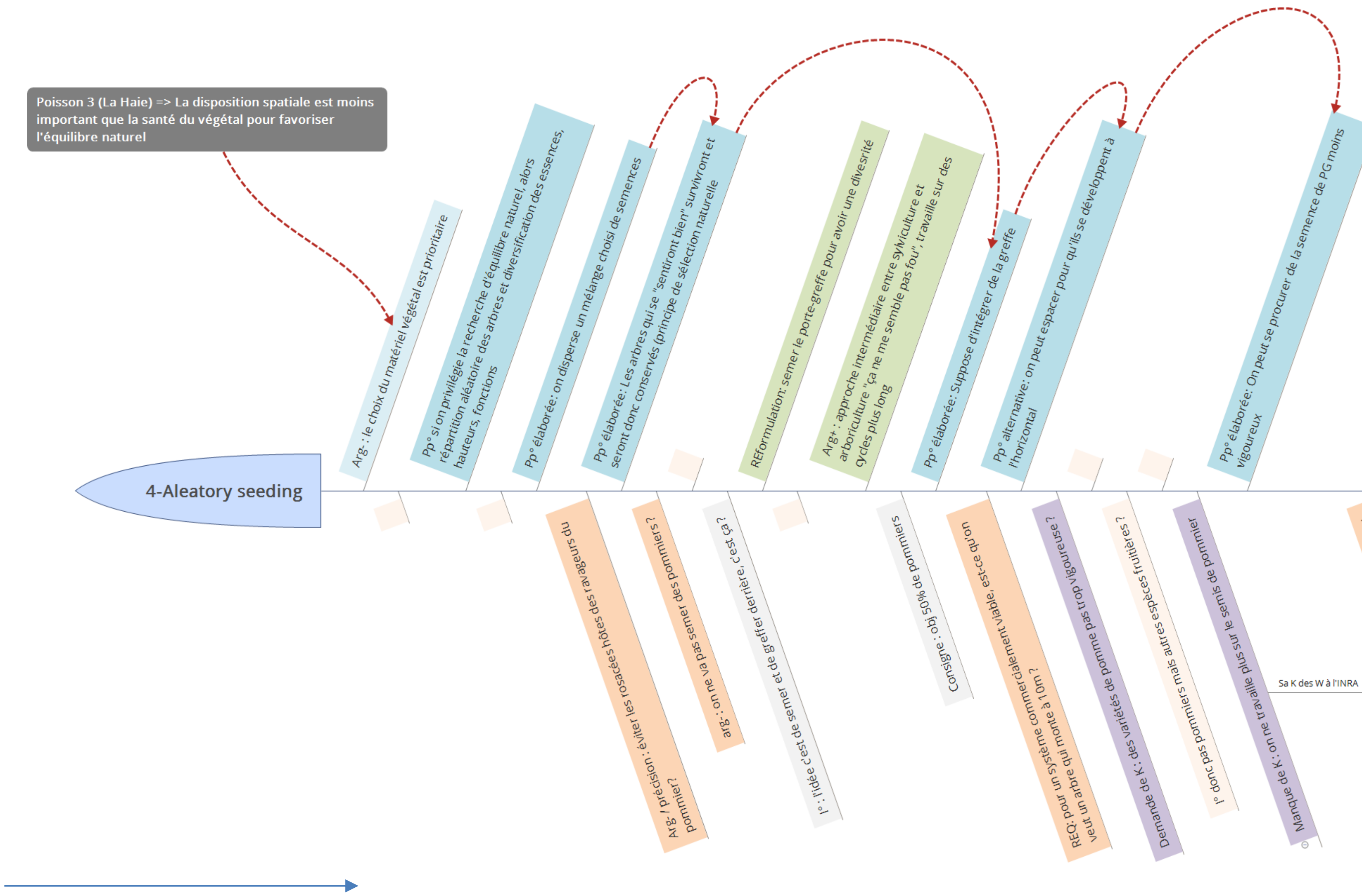
Appendix 11: Second fish-idea of table 4, the circling rows



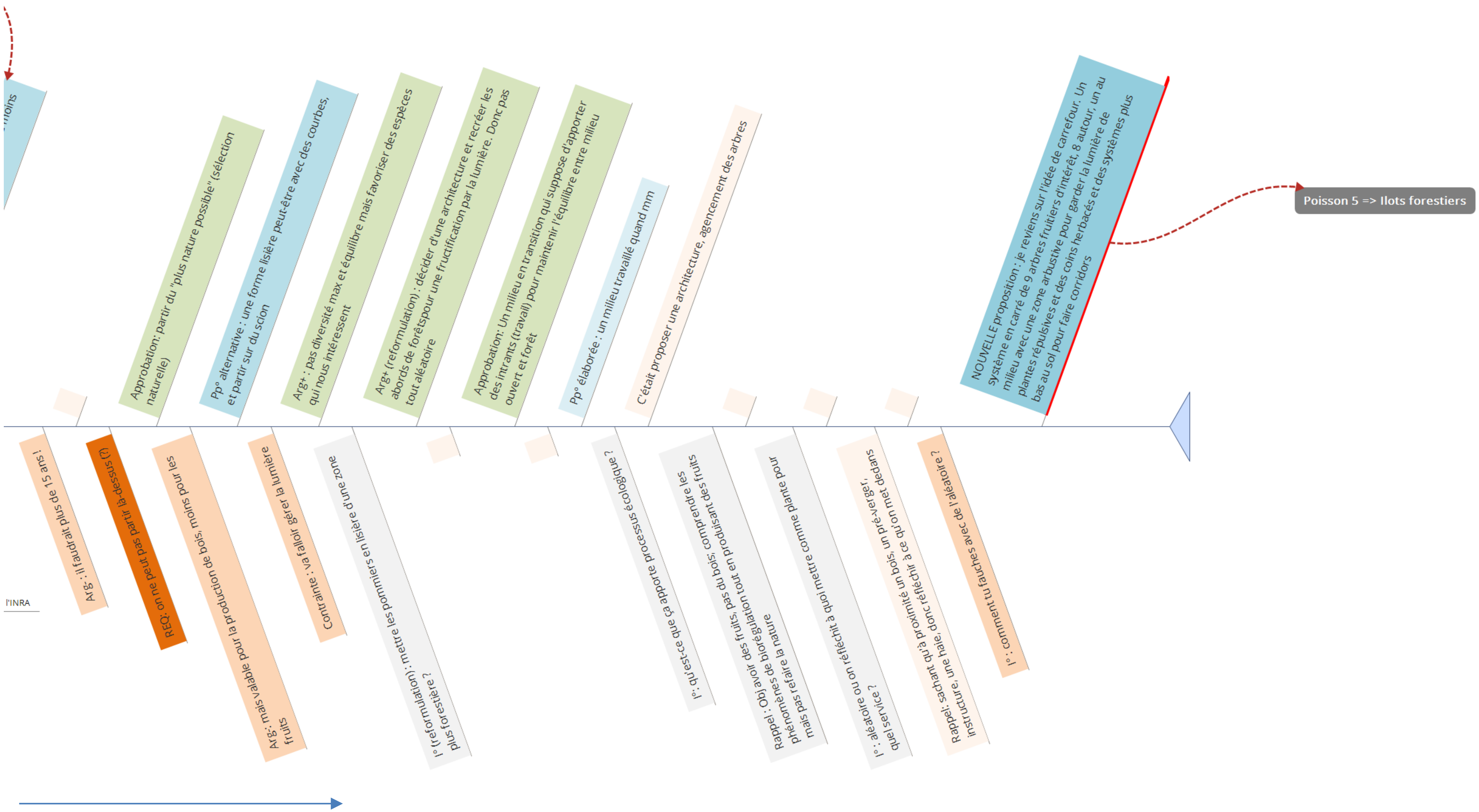
Appendix 12: Third fish-idea of table 4, the hedge



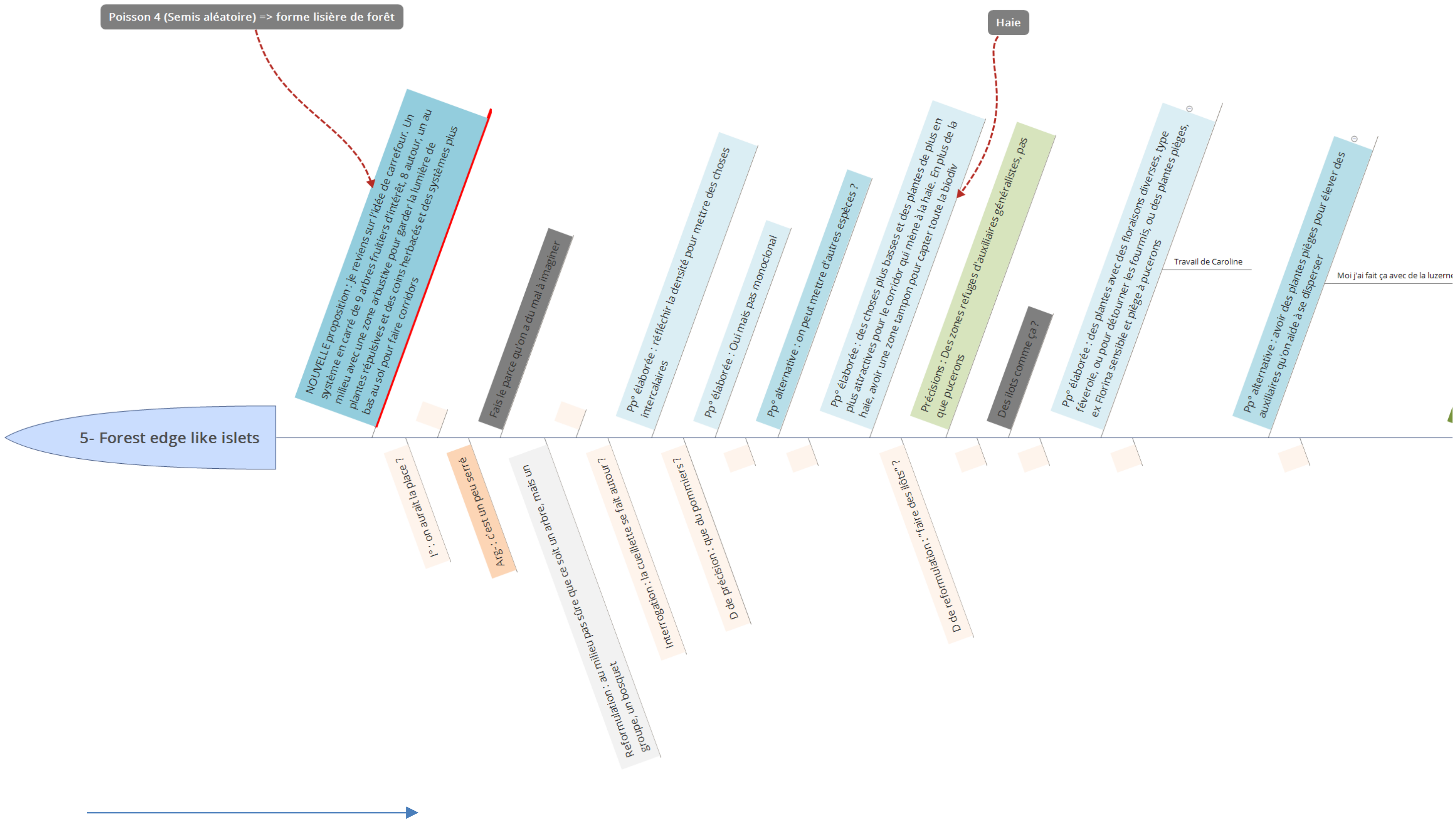
Appendix 13: The fourth fish-idea of table 4, the aleatory seeding



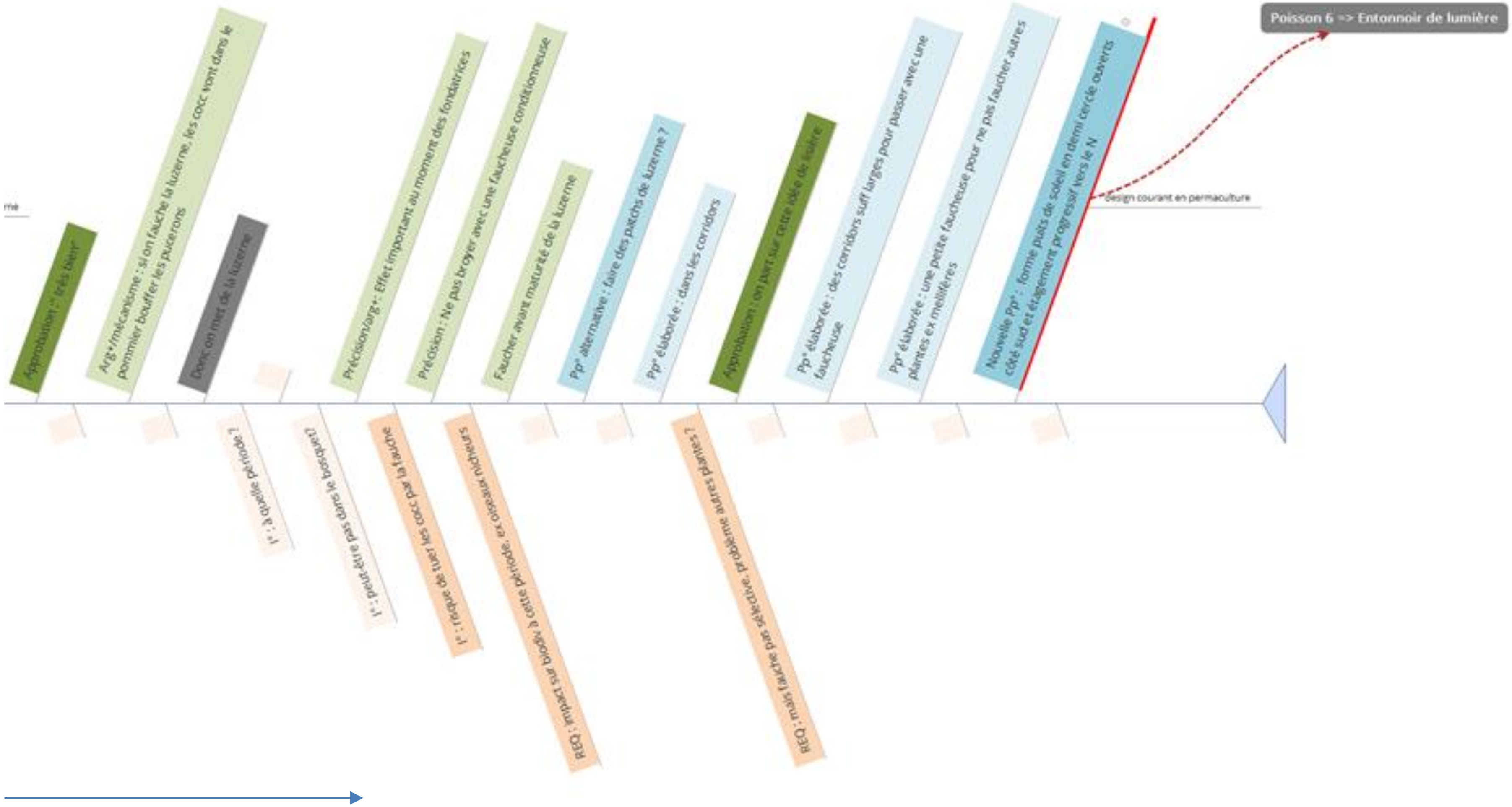
Appendix 13: The fourth fish-idea of table 4, the aleatory seeding (following)



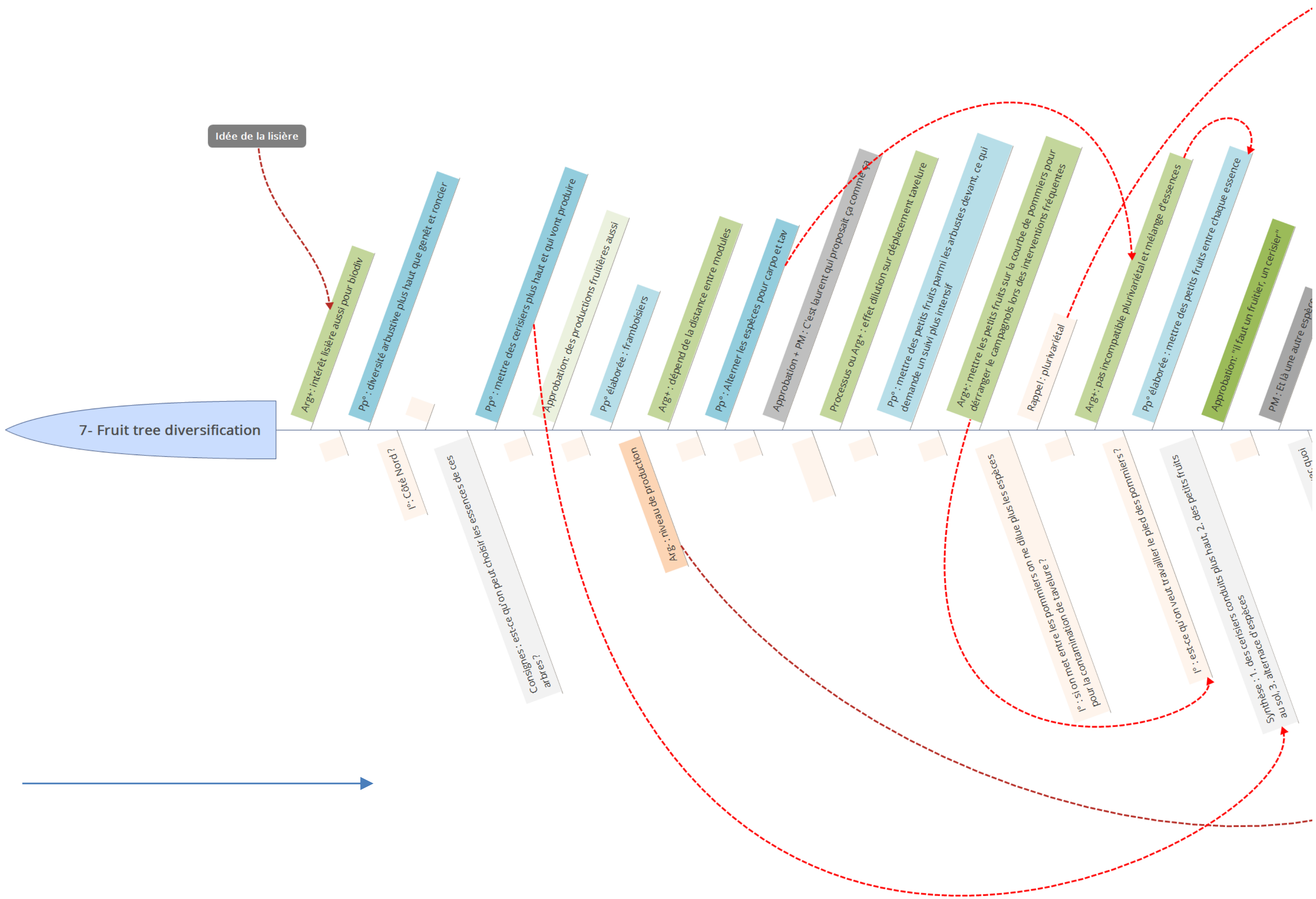
Appendix 14: The fifth fish-idea of table 4, the forest edge like islets



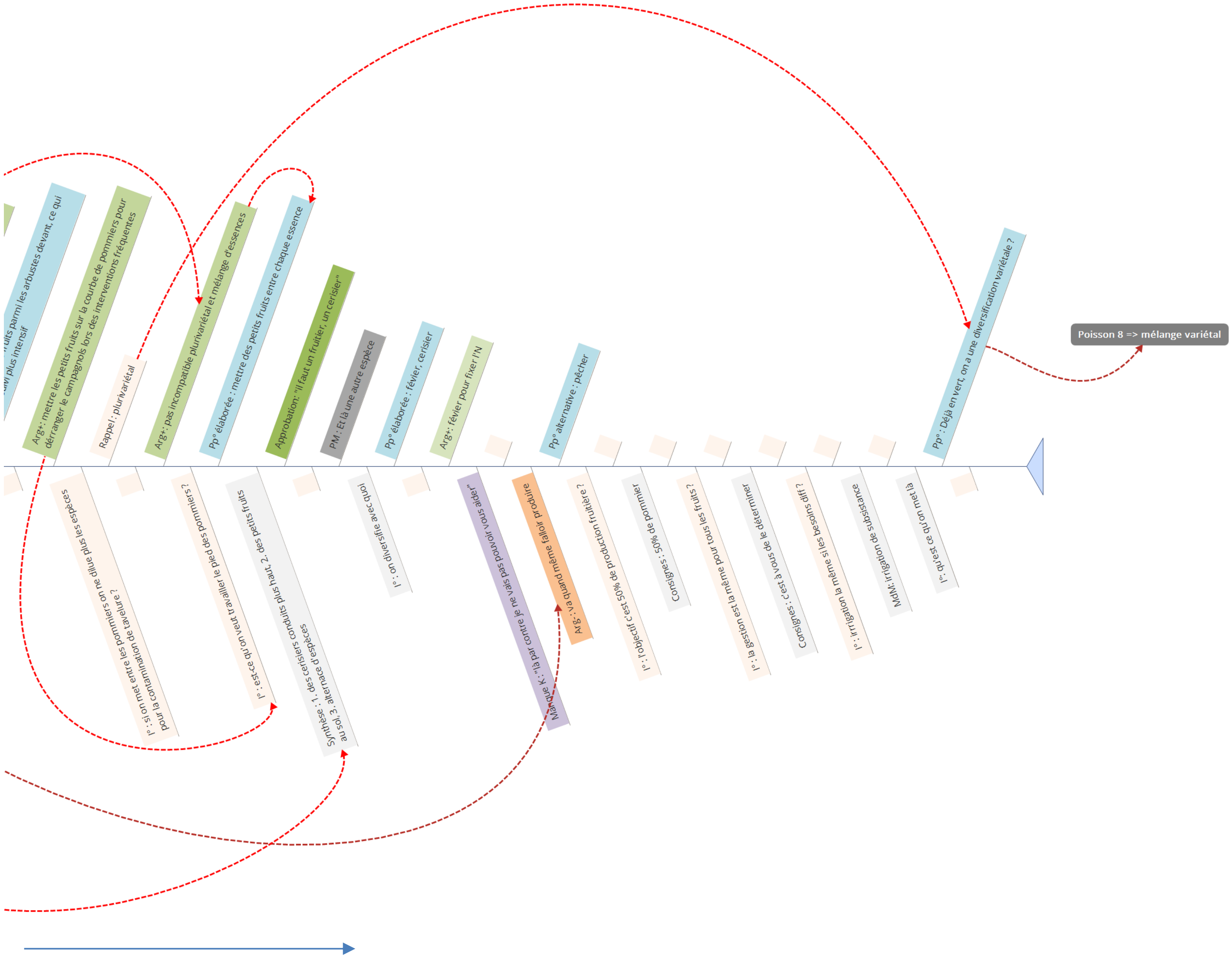
Appendix 14: The fifth fish-idea of table 4, the forest edge like islets (following)



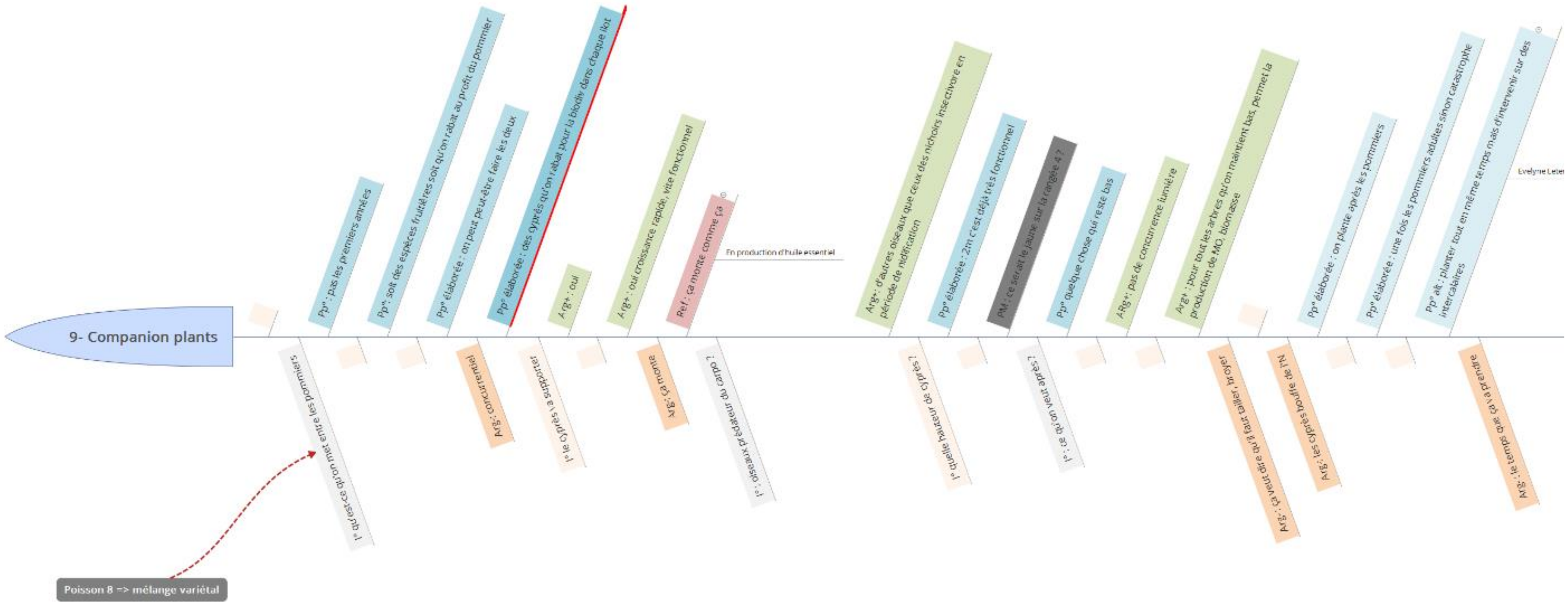
Appendix 15: The seventh fish, the fruit tree diversification



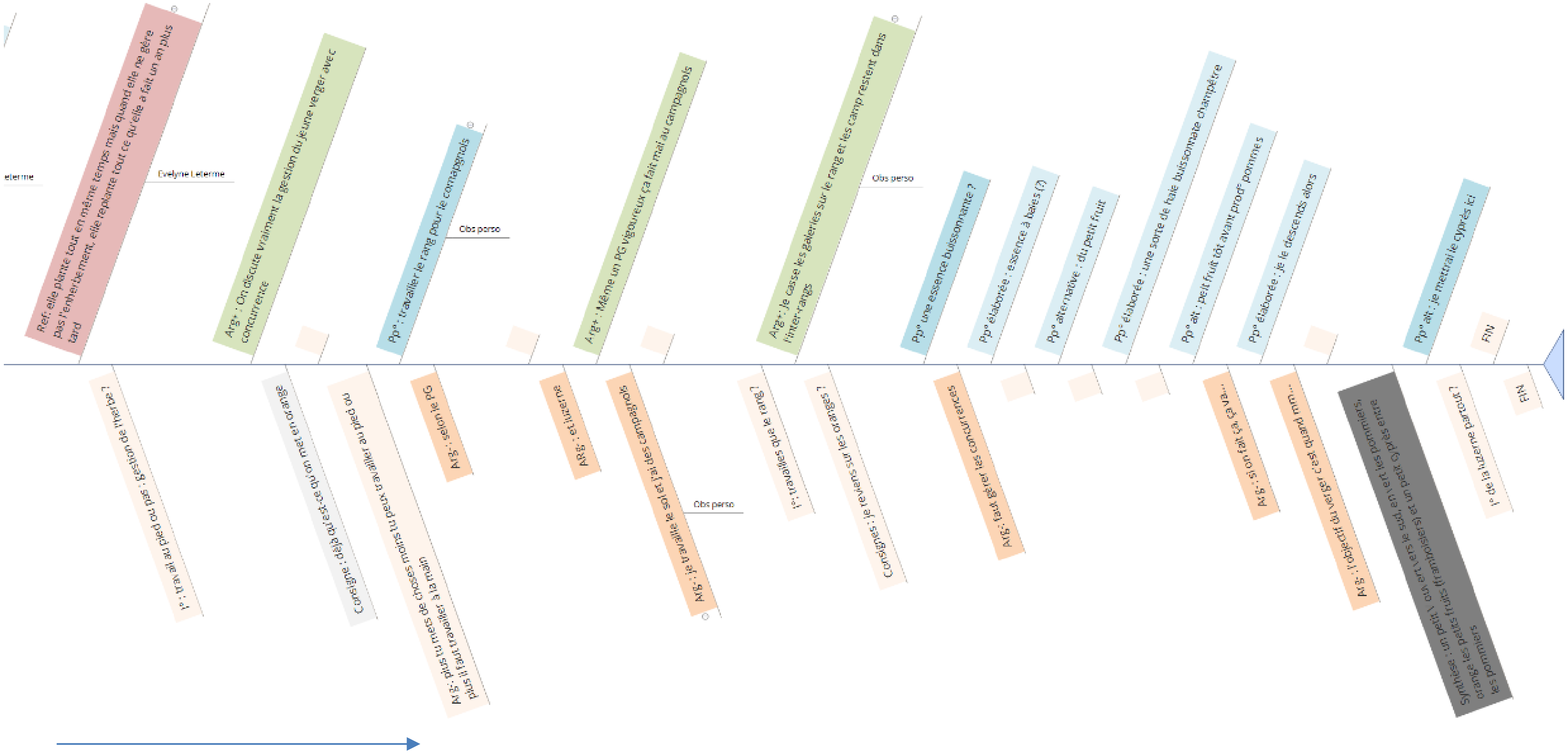
Appendix 15: The seventh fish, the fruit tree diversification (following)



Appendix 16: The ninth fish, the companion plants



Appendix 16: The ninth fish, the companion plants (following)



Appendix 17: The CK method of mapping reasing (Hatchuel et Weil, 2009)

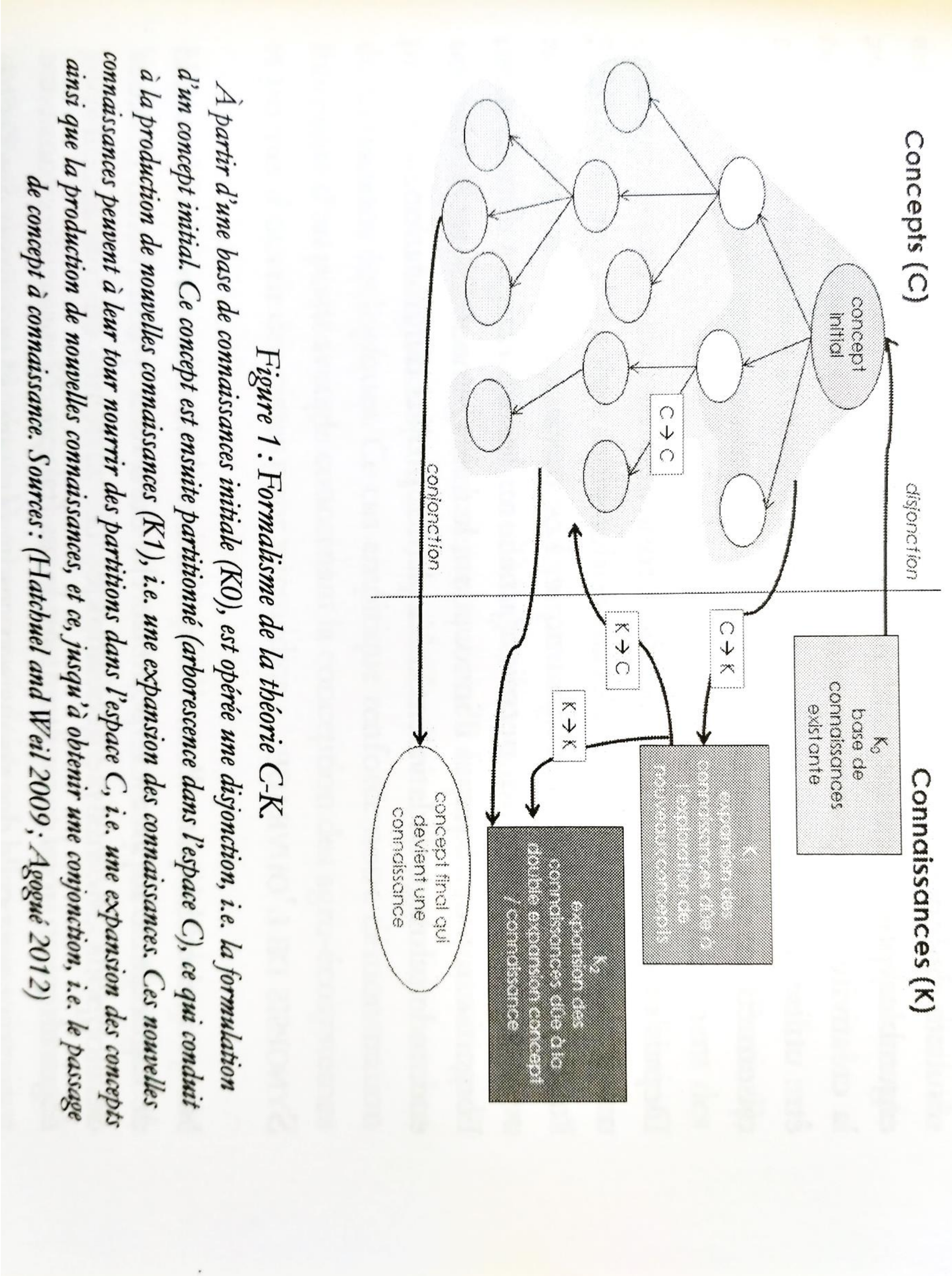


Figure 1 : Formalisme de la théorie C-K

À partir d'une base de connaissances initiale (K0), est opérée une disjonction, i.e. la formulation d'un concept initial. Ce concept est ensuite partitionné (arborescence dans l'espace C), ce qui conduit à la production de nouvelles connaissances (K1), i.e. une expansion des connaissances. Ces nouvelles connaissances peuvent à leur tour nourrir des partitions dans l'espace C, i.e. une expansion des concepts ainsi que la production de nouvelles connaissances, et ce, jusqu'à obtenir une conjonction, i.e. le passage de concept à connaissance. Sources : (Hatchuel and Weil 2009 ; Agogué 2012)

Appendix 18: The learning circle (Wilson and Morren, 1990, ch.2 p.36)

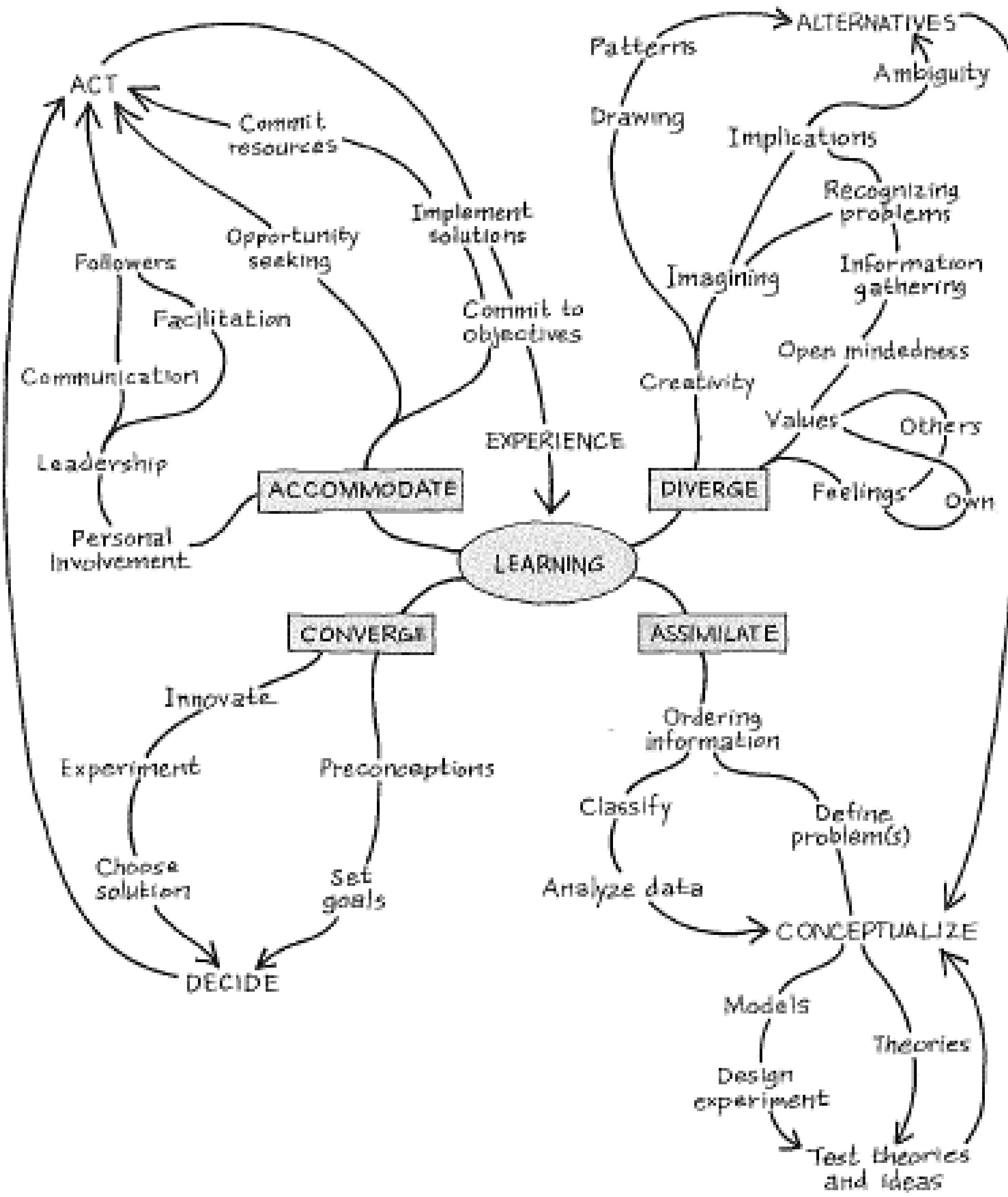


FIGURE 2.3 The learning cycle as patterned human activity.