# Sustainable orchards' redesign: at the crossroads of multiple approaches

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**Abstract**

*Apple production is among the most intensively sprayed productions. Orchards' design usually targets productivity rather than autonomy and reproducibility. However, as perennial and multi-strata systems, orchards create complex design opportunities to promote natural regulation processes and to address sustainability issues. Besides, there are specific expectations from the food-chain and the consumers for technical, aesthetical and nutritional qualities of fresh fruits. The whole society is more and more concerned with high pesticides use and its incidence on life quality (human and animal health, biodiversity, water). Therefore, an integrative approach of both agroecosystem and food-chain level has been chosen. To combine the diversity of interpretations and knowledge required to (re)design sustainable orchards, we developed an innovative participatory approach with fruit producers, advisors and agricultural scientists. It relies upon (i) expert-based knowledge to settle the objectives and properties of sustainable orchards; (ii) co-design of candidate models and (iii) ex-ante evaluation. After four years of group-functioning, we hereafter introduce major findings. First, the design of sustainable orchards entails to consider diversity, both among and within candidate models. Most of existing innovative and impressive experiences (e.g. association of animal and fruit productions) have been identified in organic or low-input commercial orchards. Key-elements for design purposes were discussed and included in a framework to design candidate prototypes. Second, a sustainable orchard appears as a dynamic entity adapting to global change and progressing towards 'higher resilience'. Methodological issues for simultaneous conception-evaluation process of prototyped systems were outlined and different tools were explored. To conclude, both diversity and dynamics of orchard models are key elements to sustain productivity and reproducibility. The most promising co-designed prototypes are now to be evaluated in various contexts covering Northern to Southern contexts of Europe within a follow-up project still to initiate.*

## 1. Introduction: Why is orchard redesign challenging?

Tree crops production are highly dependent on external inputs, namely pesticides (Sauphanor et al., 2009). Orchard design and management are indeed subject to various pressures. Three specific features help understanding the limited room for alternatives. First, orchards agricultural systems are rather specialized and perennial within the same field. Therefore, both spatial and temporal crop diversification (crop combinations or rotations) are hardly used as a method to limit pest populations and disease inoculum, recycle nutrients, or enhance energy-flows. Second, the globalization and economic integration of the horticultural sector have deep influence on farms structure (Dehnen-Schmutz et al., 2010). Orchards are dedicated to produce fresh fruits with particular expectations from both international standards and consumers. Due to both the clonal propagation of fruit trees and the concentrated demand of the market on a limited number of highly disease susceptible cultivars, the genetic diversity of current systems has become drastically low and reaches its limits (Lateur et al., 2002).Third, public incentives and policies for a reduction of chemical active compounds in the European Union settles new technical bottlenecks, e.g. pest resistance induced by the recurrent use of a limited number of pesticides whereas alternative methods to chemicals are not always available and/or highly efficient in currently-designed orchards, and the combined use of alternative methods is poorly documented (Simon et al 2011). As a result current orchards' have rarely been designed and managed targeting autonomy and reproducibility. However, the context is changing. Factors encouraging fruit growers to reconsider their orchards' design and management are numerous and include: the low profit margins in the conventional food-chain, the increasing cost of labor and energy, the environmental awareness among consumers, producers and policy-makers, while successful new practices and marketing organizations demonstrate potential alternatives (Habib et al., 2000). The combination of challenges in fruit production pleads for an urgent need to investigate integrative approaches both at agroecosystem and food-chain level to minimize reliance on external inputs; integrative also in the sense that only a set of solutions may respond to such multi-level, multi-actors and interdependent challenges (Lamine, 2011). Partial and fragmented proposals must thus be combined and integrated within a system approach.

In the perspective of a transition towards a more sustainable agriculture, the ESR framework identifies three approaches (Hill and MacRae, 1996): input-Efficiency (making the best choice and use of pesticides in order to reduce their overall use), input-Substitution (replacing chemical pesticides with biological ones) and system-Redesign (reorganizing production systems according to ecological principles). The two first options do not entail profound changes and do not solve the problem of external-input-dependency. In contrast, the system redesign entails a paradigm shift, arising from the transformation of system functions and structure to a more holistic way through the construction of diversified production systems. Diversity promotes interactions between components of the 'agro-eco-system', enhance natural regulation processes, and therefore help sustaining fertility, productivity and resilience. Considering orchards as agroecosystems do not only provide opportunities for adopting an ecological approach of pest management but more generally to global system redesign (Bellon et al., 2007; Hill et al., 1999; Lamine, 2011; Vandermeer, 1995). Orchard's structure and longevity have to be seen as opportunities to enhance ecosystem processes, rather than seeing them as constraints. Tree architecture and orchards' multi-strata structure create a complex design likely to fulfill niche requirements of many species and promote natural regulation processes through the provision of resources and shelters for many organisms (Simon et al., 2010). And these functions are reinforced by orchard's temporal and spatial stability (Brown, 1999).

But if the demand for less-pesticide dependent practices is increasing, alternative methods to chemicals are not always available or easy to implement in current orchards, since there are very scarce references on the combined use of several alternative methods and their interactions within the production systems and with its environment (Hill et al., 1999; Jamar, 2011; Simon et al., 2011). Redesign tree crop production on other bases becomes a necessity both for research workers and practitioners. Such a paradigm shift represents a major change in the concepts and knowledge to be mobilized, e.g. ecology, for redesign. This pleads for an urgent need to investigate disruptive rather than incremental innovations and 'innovative' rather than 'rule-based' design (Martin et al., 2012; Meynard et al., 2012). Innovative design aims at satisfying new expectations what makes it impossible to specify *a priori* the required skills and evaluation methods. Creativity – based on a multidisciplinary approach - is thus required, not only to build on scientific, technical and lay knowledge, but also in the design process itself. In this scope a working group was created in 2008, comprising organic producers, advisors and researchers from various disciplines,institutions, and European countries. The first objective of the group was to identify and discuss (i) properties of sustainable orchards; (ii) potential innovations and assessment tools to design, manage and evaluate sustainable orchards. Organic farming is here considered as an example of model based on such global approach of the production system (Dapena et al., 2005; Wyss et al., 2005; Zehnder et al., 2007), although some similarities exist with the ambitions of Integrated Fruit Production (IFP) as suggested by IOBC[1] and other authors (Habib et al., 2000). Organic principles promote global solutions and integrative approaches, rather than targeting a single problem (Lotter, 2003). Still, as for conventional systems, it faces different degrees of eco-design since input-substitution rather than redesign prevails in some organic orchards (Bellon et al., 2007; Penvern et al., 2010). However, the participating organic growers are all interested and involved in redesign issues, with a prospective vision of sustainable orchards. Not all participants are dedicated to research or extension in organic farming. Such linkages with other forms of agriculture, such as integrated fruit production or biodynamic farming, enable us to extend the validity domain of our proposals and to enhance interactions with other experiences. Organic farming provides yet an interesting framework and baseline for our group, while considering both its present situation and its evolution capability.

This paper presents the main achievements of the mixed group which addressed the issue of redesigning orchards through a participatory approach. It also aims to analyse the group's functioning and its major findings in light of its ambitions.

## 2. Materials & Methods

The literature on system design methodologies is substantial, emphasizing the different approaches and methodologies, their potentials and limits. Recent studies propose a classification of these different approaches based on the degree of stakeholder participation and support process (Le Gal et al., 2011), on the degree of reconfiguration (Meynard et al., 2012), or on the nature and degree of the exploration of the solution space either computational or knowledge creative (Martin et al., 2012). Concerning tree crop production, different methodologies have already been used for orchards design including expert-based design (Lescourret and Sauphanor, 2010), model-based design (Ould-Sidi and Lescourret, 2011), or prototyping methodologies (Kabourakis, 1996). We developed a design process combining an expert participatory-based approach with an optimization approach for ex-post assessment; the latter used the DEXiPM Apple tool (unpublished), newly adapted from the DEXiPM® model originally designed for arable cropping systems (Lô Pelzer et al., 2009). Our global approach hardly follows a linear process but rather iterative and integrated. Nevertheless, the following major steps can be identified: problems identification, prototypes exploration, evaluation and selection of prototypes. Loops are continuously occurring

[1] International Organisation for Biological Control

### 2.1 Enhancing collective expertise

We adopted a participatory approach to identify alternatives, study their combination, implementation conditions and consequences for the conception of innovative sustainable orchards. To do so, a working group gathering fruit growers, advisors and scientists with a common motivation to design more sustainable orchards was constituted. Apart from historic drivers occurring when constituting a working group, farmers and advisors are known to be central stakeholders in the production processes when dealing with innovative systems (Le Gal et al., 2011). Such participatory approach allows us to (i) integrate existing local and farmers' knowledge with scientific knowledge (ii) embrace the goals of various actors, (iii) integrate site specificities from different regions and countries to ensure the conception of realistic and reproducible prototypes and define their domain of validity, and to (iv) deal with decision-making and rule-based processes.

The group has met five times since 2008 for experience and science sharing, brainstorming and orchards' visits on dedicated topics. The group brings together 24 permanent French-Speaking participants from France, Belgium, Spain and Switzerland. It includes 8 researchers from various domains such as fruit growing, entomology and phytopathology, tree physiology, genetic resources and fruit breeding, ecology, 6 fruit growers (5 certified in organic farming), 9 advisors and 1 teacher, along with invited guests. Each meeting permitted to discuss/evaluate which levers and assessment tools were relevant to design, manage and assess sustainable orchards. The topics addressed were chronologically the following: (1) the tree – choice of cultivars and rootstocks interaction, (2) the agroecosystem, (3) the agri-food system, (4) methodology for sustainability assessment, (5) alternative systems design. At each meeting, invited key speakers and visits of innovative orchards from growers or research experimental sites were programed in order to progress and discuss levers and implementation conditions.

### 2.2 An orchards' network

(Re)design is often an interactive process involving both conceptual abstraction and active experimentation (Meynard et al., 2012). We combine different type of orchards: experimental orchards from research and extension institutes from different countries (INRA Gotheron in France, SERIDA experimentation in Spain, CRA-W Gembloux in Belgium ...) whose results were discussed in the group; and commercial orchards of some fruit growers members of the group. In addition, we visited commercial or experimental orchards in the region of each meeting according to the topic of each meeting. For instance we visited young apple orchards planted extensively in association with other species (chestnut and cherry trees ...) pointing out multiple questions on the transition process and constrains to support such transition. We also visited an innovative experimentation that associates fruit and vegetable production on the same plot emphasizing technical and economic constrains to conduct both productions on the farm at the same time.

### 2.3 A participatory modelling approach

We combined a participatory expert-based with a model-based design. The group participated at each stage of the following design process: when identifying the main issues to be addressed, when providing criteria and data to be considered into models or experiments, when defining the structure and content of the models or experiments, when selecting innovative systems, or when evaluating the systems that are being tested or modeled. Commercial farms served as reference and thus ensured the credibility and feasibility of the prototype tested for fruit growers. However, participatory-based methods take time, may place greater emphasis on qualitative global evaluation, and constrain the experimentation to small plots easier and less risky to manage (Le Gal et al., 2011). As a complement, model-based or *in silico* design permits to explore breakthrough scenarios which can't be observed in farmers' fields. In our case, the use of DEXiPM_Apple, a hierarchical qualitative multi-criteria model, allowed us to (i) describe the system and its components as well as the context of the assessment, (ii) compare different *in situ* or *in silico* orchards design, and (iii) identify key-elements that contribute to sustainability. DEXiPM_Apple tool is based on the DEXiPM® model originally designed for arable cropping systems (Pelzer et *al.*, 2012) and is supported by the software DEXi (Bohanec *et al.*, 2008). It is based on a decision tree breaking the decisional problem of sustainability assessment down into simpler units, referring to the economic, social and environmental dimensions of sustainability. The aggregation processes in the decision tree are based on 'if-then' qualitative rules and the importance of each criterion is characterized by weights and rules defined by users and experts.

The collective definition of 'more sustainable orchards' and the evaluation criteria constrained the expert group to agree on common objectives and indicators despite different interpretations and local specificities. We explored mental models to improve our understanding and formalized the diversity of stakeholder's representations of a sustainable orchard. Traditionally used for natural resources management such as water in the Camargue Biosphere Reserve (Mathevet et al., 2011), its originality lies in the co-construction of a shared 'conceptual model' of the relationships and functioning of the different aspects of a particular system or territory. This approach is implemented by organizing workshops with stakeholders who identify and elicit the Actors, Resources, Dynamics (processes), and Interactions (ARDI) that constitute the main drivers and state variables of the social-ecological system. To do this, the participants collectively answer four questions using system diagrams. The method follows several steps described by Etienne et al. (2011).

To conclude, our approach relies on the assemblage of different approaches to design more sustainable orchards:

- integrating various interpretations, objectives and local specificities from an heterogeneous working group gathering growers, advisors and researchers from different countries;
- combining a participatory expert-based with a model-based design;
- *in silico* and *in situ* experimentation, with commercial and experimental orchards, implementing, which are important tools to implement all potential levers, either systemic or biotechnical innovations, identified in the group.
- evolutionary process in time and space by organizing one meeting per year – each time at a different place and linked to a key partner – that permits for the partners to progressively integrate the various conclusions from the dynamic interactions and synergies that occurs from the group.

## 3. Results

### 3.1 Co-design: A framework for more sustainable orchard design

Most of the innovative and referenced experiences (such as association of animal and fruit productions) have been identified in organic and low-input commercial orchards. We also explored the agro-food system level to analyse interactions between technical choices and socio-economic performances. Economic issues emphasized the importance of input-autonomy properties, the adaptation to market and consumption patterns, and diversification of the production systems to reduce vulnerability and finally, the urgent need to develop 'North-North Fairtrade concepts. In an attempt to break away with existing systems, expected properties of sustainable orchards were discussed and expressed in a framework to design candidate prototypes (Text-box 1).

**Text-box 1: Key properties of a more sustainable orchard**

1 **The short term productivity includes the preparation of the sustainable long term productivity.** It means that all actions realized into the sustainable agroecosystem context should target natural resources preservations at local and non-local level, whatever the orchard design.

2-**Multiple and reproducible under various conditions**. As basic concept, it is obvious that there are multiple models of sustainable orchards; each of them requiring adaptations to local specificities (pedo-climatic conditions, pest and disease pressures, socio-economic context, etc.). Their definition thus entails gathering generic recommendations along with decision support tools for local implementation and adaptation by practitioners.

3-**Robust and resilient.** This is particularly relevant for the many disturbances (pests and diseases, climatic, or commercial) systems are likely to absorb. These properties should be achieved by nurturing the ecosystemic services derived from optimized agro-biodiversity designs that encourage synergies and efficient use of locally available resources. Consequences are a minimum use of external inputs, including labor and technical requirements.

4-**Flexible.** Sustainable orchards should have the capacity to evolve and adapt to unpredictable changes (input prices, consumers' preferences, climate change …). Diversity is a key-element representing a buffer as well as a pool of alternative options to face disturbance. Such diversification may concern knowledge, skills, cultivars, species, cultural practices, source of incomes, commercial channels, etc.

5-**High value and high-quality production.** A production of a high value should be achieved to ensure high quality products, environment and living conditions (including income insurance, duration and condition of works). For example cultivars and management practices should be chosen to maximize nutritional value, minimize pollution and human intervention.

This framework is not definitive but it presents our understanding of the concept of 'sustainable orchard'. The mental model allowed us to identify key-actors, -resources and -processes for sustainable orcharding. Matched stakeholders were mentioned, among which in order of occurrence: fruit growers, advisors, consumers, policy-makers and distributors. Resources were always different, except for the soil and biodiversity, recognized as major resources for a sustainable orchard. The definition of precise (re)design objectives represents thus a great challenge due to:

- Uncertainty about the future whereas a new orchard is planted for at least ten to fifteen years,.
- Lack of knowledge and operational alternatives,
- Unconscious bottlenecks due to existing systems and constrains that are hard to omit,
- Heterogeneous set of values and stakeholders.

### 3.2 Eco-design: Contribution of ecology for design purposes

Ecological and evolutionary knowledge are important tools to analyse interactions in nature and to estimate and design long-term management strategies in human driven agroecosystem. This consideration has been a key-element to orientate thinking since the beginning of the group (Bellon et al., 2009). Both top-down (through natural enemies of pests) and bottom-up (through plant traits) processes were explored to foster self-regulation properties of the orchard. To do so, multiple levels of investigation were addressed.

At the scale of the canopy, we explored biological key properties including the adapted cultivars that express a better tolerance to biotic and abiotic stresses (e.g. pest and diseases tolerance, higher fertilizing efficiency,...) combined with rootstock selection, tree physiology, and tree training with the aim to foster adaptive capacity of the sustainable orchard considered as an agroecosystem. Findings from the literature and experimental trials indicate that biological knowledge is also important to enhance bottom-up processes and increase tree health through nutrient feeding and pest tolerance. Various experiences also show that many commercial cultivars are highly susceptible to diseases and not adapted to low input farming systems (Sauphanor et al. 2009; Simon 2008), Subsequently, two of the conclusions shared by all participants was that (i) well adapted cultivar is one of the main keystone and (ii) it is very urgent to develop specific breeding activities and trial conditions that are specifically in line with organic farming system requirements e.g. properties of resilience and low input (Dapena and Blazquez, 2004; Lateur et al., 2009; Warlop et al., 2010). Plant breeding programs and orchard training systems should further consider the behaviour of the tree-rootstock complex, and their assemblages in time and space (Lateur, 2003; Lauri et al., 2008; Miñarro and Dapena, 2010). For instance, the breakdown of the scab *Vf* resistance by at least three scab races emphasizes the importance to broaden the genetic diversity of scab resistance including quantitative resistance (Lateur and Doucet, 2006). Alternative interesting traits should be considered such as: high tolerance to most diseases, natural tree habit easy to manage, low fertilizer requirements, diversity of tree architecture (Lateur, 2003; Miñarro and Dapena, 2007; Warlop et al., 2010). Rescue surveys pointed out that many landraces are still present in old orchards or gardens and may be used either as cultivated cultivars for local market or as parent in breeding programs (Lateur, 2003). Cultural practices and in particular tree architecture and physiology manipulation through tree pruning, tree training and thinning, and tree feeding should also be integrated to achieve more regular yield, higher fruit quality and fewer pesticides use (Lauri et al., 2008).

At the scale of the agroecosystem, we explored ecological bases to maximise orchard self-regulation properties. Biodiversity was identified as a corner-stone to enhance the effectiveness of natural enemies of pests (Jamar, 2011; Miñarro et al., 2005). Innovations can be fostered by increased interactions between crop production and protection, encompassing higher levels of organization – beyond the tree or the orchard – namely to integrate ecological infrastructures as functional elements of agroecosystems. This would include (i) maintenance of within-rows grass cover, cover crops and mulches and (ii) habitat management to trap or repel overwintering pests and to support natural pest control (Simon et al., 2010). A self-regulating system also relies on nutrient recycling. In this perspective, we also explored soil fertility management through organic amendements and rameal chipped wood or more radical innovations based on biodiversification integrating animal husbandry (Rey and Coulombel, 2008) or shrubs as an intermediate strata, at least temporarily in orchards trajectories. Other perennial models integrating trees such as agroforestry initiatives and permaculture principles were also explored to explore systemic basis for eco-design.

### 3.3 Evaluation of prototypes

The essential multi-dimensional and dynamic nature of sustainability challenges the use of composite measurement indices. Easy to use and not too time-consuming, DEXiPM_Apple has been used as a « dashboard » to show the value of all criteria and discuss performances of the different systems. In Figure 1, two tested orchards show an improved global sustainability as compared to a conventional French orchard. However, farmer 1's orchard presented a lower global sustainability explained by a lower environmental sustainability compared to farmer 2's orchard. We identified context parameter (climatic conditions facilitating the pollution transfer) and a different orchard setup (with different understory management), which explained the lower performances of farmer1's orchard.

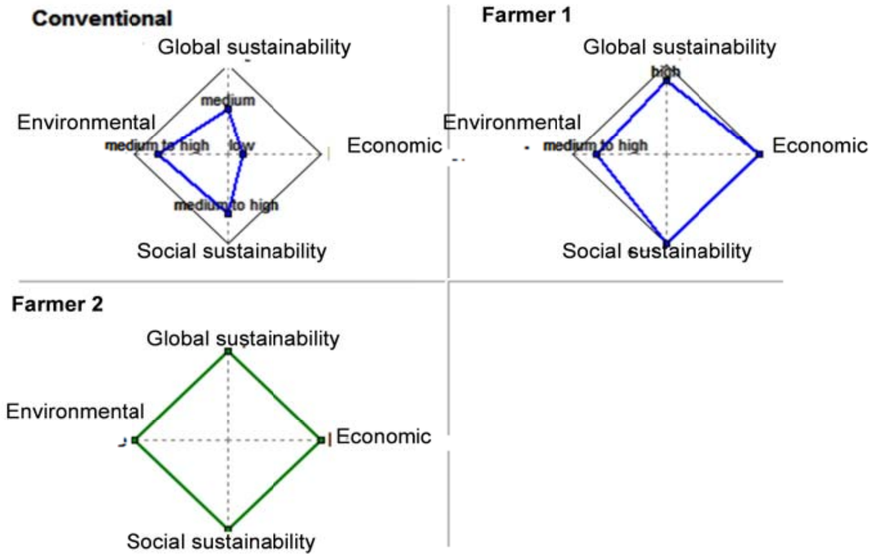


Figure1. DEXiPM-Apple evaluation of three apple production systems (one conventional and two organic systems), both on the global and the three pillars of sustainability.

DEXi-PM_Apple also represents an opportunity for simulation-based design. It would enable a very wide exploration of prototypes that would be collectively defined. Furthermore, interactions between modellers and experts permit discussions on the accuracy of the criteria and indicators used to assess sustainability and contribute to build a common definition of a sustainable orchard.

## 4. Discussion & Perspectives

### 4.1 A diversity of eligible models

Since sustainability itself can only be operationalized in context, universal ideal farming systems do not exist (Meynard et al., 2012). Redesign of farming systems thus has to (i) prepare for a diversity of solutions, leave the choice to farmers and other stakeholders and prepare different futures; and (ii) help stakeholders to adapt these systems to their own situation, and to build their own compromises, relying on their own knowledge. We are still in the exploration phase since farmers, advisors and researchers design innovative production systems for their own purposes. These models should be further discussed in terms of limits and opportunities towards sustainability to define solution spaces and settle different prototypes with increasing degrees of disruption. In this perspective, orchard observations and stakeholders' involvement are necessary tools to perform a diagnosis, identify gaps in biotechnical knowledge to better fit design process to farmer's context of actions. A pool of potentially innovative systems could thereby be constituted from which farmers, advisors and researchers could draw solutions according to their own objectives and value sets. Monitoring surveys should be performed on the already experimental and innovative orchards' network. Yet, indicators are still in construction and must carefully be defined according to the expected properties of sustainable orchards, their accessibility for farmers or advisors, and the heterogeneity of local specificities. In addition, the use of ex-ante modeling represents an opportunity to test *in silico* different prototypes before their implementation into field experiments, especially since *in situ* experiments are costly and time consuming when dealing with perennial systems.

### 4.2 Assessing the orchard agroecosystem dynamics

We suggest that sustainable orchards should not only be evaluated according to their performance at a given time, but also in terms of dynamics to inform their resilience and flexibility, essential prerequisite of sustainability (Milestad et al., 2012). This largely depends on (i) knowledge and creativity, (ii) long-term action logics, and (iii) adjustment capacity through redesign. Orchards are often described in static terms and current evaluation frameworks often fail to inform their capacity to face uncertain change, either by absorbing disturbance (resilience), or by evolving (flexibility). Evolutionary systems do not relate to stability in a static sense as they face a moving equilibrium and the dynamics of co-evolutionary interactions that cannot be foreseen *ex-ante.* A new framework with a new set of indicators is thus necessary, giving even more emphasis to the first phase of the design process for the definition of objectives and system properties. Most design methodologies rely on an iterative process based on improvement loops. However, contrary to rule-based design where rule-sets are modified when necessary while objectives and constraints assigned to production systems remain fixed (Debaeke et al., 2009), our approach is intended to be reflexive and adaptive to modify the desired objectives, as well as the fields of knowledge. Besides, improving the understanding of systems' dynamics should help support farmers transition towards redesign. Decision-aid modeling helps producing recommendations and identifying targeted technologies or potential pathways of farm evolution by comparing simulated scenarios with farmers' management strategies. However, specific and variable tempos of farmers' trajectories are necessary factors to consider for a robust ecologization of agricultural practices (Lamine, 2011). To do so, the prototyping method is adapted. Exploration is more cautious, but it integrates specific constraints of each farming situation. This entails to follow a step-by-step design, performed on farm and/or on experimental orchards, where decision-rules must be recorded. This could be made on the basis of candidate prototype formerly defined through our expert-based and model-based methods.

Co-designing as a cornerstone, also strengthening individual initiatives: As mentioned above, the design of farming systems entails partnership and collective dimension. Co-design appears as a good approach to define the properties and architecture of such complex systems combining multiple objectives and processes. When using mental models, we expected that after four years of running, system models wouldn't at the end differ much among members. But resources differed significantly, emphasizing the care that must be taken to agree on common objectives for sustainable orchards design or redesign. Such a definition represents thus a great challenge considering the multiple lexical qualification and meanings of a same word (e.g. "sustainable" or "orchard"). The use of mental models also proved to be an interesting tool, but may require longer and specific sessions. In terms of perspectives, our findings should then be confronted within a wider group or within a different one to test the genericity of our definition of a sustainable orchard. One of the not predicable goal achieved during this co-design process is the unbelievable number of ideas that raised from our meetings with the practical consequence that when going back home, each partner was able to create innovative and adapted new and pragmatic actions in his/her sphere of influence. It would be very interesting to develop specific model of investigation for monitoring such results.

## 5. Conclusion

To conclude, on the one hand, the structured participatory expert-based approach with its rich diversity of experts and the dynamic exchanges inside and outside the group, highly contributed as a nursery of valuable and innovative progresses towards more sustainable orchard agroecosystems. On the other hand, different design approaches may be complementary and play a role at different steps of the design process. The co-design mental approach is thus helpful to bring together players to agree on the values of a "sustainable orchard". Once this is established, a participatory model-based approach with experts having a variety of skills on a shared redesign project enables to define the objectives and imagine prototypes. Then, prototypes may be implemented in a prototyping design process for continuous improvement and dissemination. The most promising co-designed prototypes should now be evaluated in various contexts covering Northern to Southern contexts of Europe within a specific project to initiate. The trickiest step remains the definition of the properties of a sustainable system given the complexity of objectives and interactions among actions and system components. Other methodological issues are the integration of the various eligible prototypes and the assessment of systems dynamics.

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