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AGROFORESTRY MARKET GARDENING: A STRATEGIC CHOICE TO IMPROVE SUSTAINABILITY IN AGROECOLOGICAL TRANSITION?

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A B S T R A C T

Among the various forms of agroforestry, spatial combinations of fruit trees and diversified vegetable growing (also called market gardening) are currently experiencing strong growth in France. The SMART project, which brought together several research teams and development organisations, aimed to explore these systems, taking into account the technical, agro and socio-economic dimensions/traits. The results of the surveys and observations carried out among farmers associated with this project showed that these systems mainly concerned farms engaged in short food supply chains for which diversity was a central element for commercial strategy and performance. Diversification of products is therefore a central justification for the intercropping of fruit trees and shrubs with vegetables. SMART also sought to assess the effects of synergies and competitions of agroforestry, as perceived by the farmers. The vast majority of them considered that intercropping fruit trees and vegetables did not create a major problem in terms of work organisation. They considered that it did not create competition which could have a negative impact on the productivity of crops. Their certainty in this respect was rather limited, given the generally short duration of their experience. However, the assessment they were making today led most of them to consider that the choice of agroforestry was fully justified and could be recommended to other market gardeners. These first results showed the need, when evaluating such systems, to adopt dynamic and holistic viewpoint on the different performance levels, allowing to consider the evolution of the trade-offs between advantages and disadvantages of such type of agroforestry on the long-term basis.

Keywords: Agroecology, agroforestry, market gardening; trade-off, performance levels, resilience.

INTRODUCTION

Agroforestry is one of the most effective agricultural land use patterns for the agro-ecological transition (Gliessman, 1995; Griffon & Mallet, 1999). Its responses indeed to the principles that should govern the design of sustainable agro-ecosystems: optimisation of the material, water and energy cycling; heterogeneity in the architecture of cultivated areas favouring the natural regulation of diseases and pests; diversity of crops ensuring resilience to exogenous hazards; protection of resources, water, soil and biodiversity (Altieri, 1989). Agroforestry is a long-standing practice in tropical areas (Nair, 1993), where it is once again developing with proven success for viability and sustainability of family farming (Prahbu *et al.,* 2015). In France, agroforestry is now part of the program of agricultural research institutes (Duru *et al.,* 2015) and public policies for agro-ecological transition (Dubois, 2016). However, as in other developed and temperate countries, agroforestry remains a marginal practice, for reasons that are often more cultural than economic or technical (Louah, 2016). Agricultural modernisation has also involved the exclusion trees from cultivated areas. This exclusion has gradually been built up in a technical culture of landscape homogenisation, making it difficult for farmers to adopt agroforestry systems. A notable exception to this mechanism of tree exclusion is the

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family gardens, where vegetables often co-exist with perennial plants, fruit shrubs and trees. This may explain the present emergence of a particular form of professional agroforestry, associating trees (most often fruit trees) and market gardening, which has been taking place in France in the past few years. It is most often found on organic farms, cultivating small areas, which sell their products through short supply channels. This type of farm is itself currently under strong development. The extension and advisory structures responsible for supporting feel the need to improve their understanding of agroforestery combined with market gardening: what are the strategic reasons behind? What are the advantages and disadvantages of such choice in terms of agronomics, work organisation, production and economic results?.These questions were at the heart of the SMART program, steered by the French Agroforestry Association (AFAF) and the Research Group for Organic Farming (GRAB), together with 14 other partners including three INRA research teams. This project, conducted from September 2014 to June 2017, was funded by the Ministry of Agriculture under the CASDAR call "Innovations and Partnerships".

To launch this process, the partners of the project offered an online questionnaire to map farms experiencing marketing gardening agroforestry. Some of these farms were then involved in a survey to describe their structure, the organization of their agroforestry plots and their motivations. This information has been enriched for some of them by in-depth measurements, including accounting, crop yield in different agroforestry configurations, and farm biodiversity. This article focuses on how farmers perceived the advantages and disadvantages of tree - vegetable intercropping and justified their choice of this system. It also debates on these perceptions by comparing them with the reality observed on the farms, but is limited to those factors for which there are sufficiently robust results

MATERIALS AND METHODS

Sample of farms: About 250 responses have been collected by the online questionnaire in the time of the SMART project (By the end of 2015, more than 150 farmers have replied to the online questionnaire, which is still open, http://www.agroforesterie.fr/ SMART/smart-agroforesterie-maraichage-participez-au-projet.php), but a total of 126 responses were analysed. The corresponding farms were located in almost all French regions, with a predominance of Occitania (41), Provence (32), Rhône Alpes (14) and Normandy Regions (12). Three-quarters were established after 2009 (Figure 1). The farms are generally small-sized: 63% of them have less than 5 hectares. However, this size corresponds to the usual surface area for market gardening farms. The smallest farms are also the most recently created. Among them, 28 claim to be inspired by permaculture, an agroecosystem design method in which agroforestry has a great importance (Mollison & Holmgren, 1978). Recently popularised in France, permaculture is now a reference for organic market gardening systems claiming to live on very small areas cultivated (Morel & Léger, 2016.

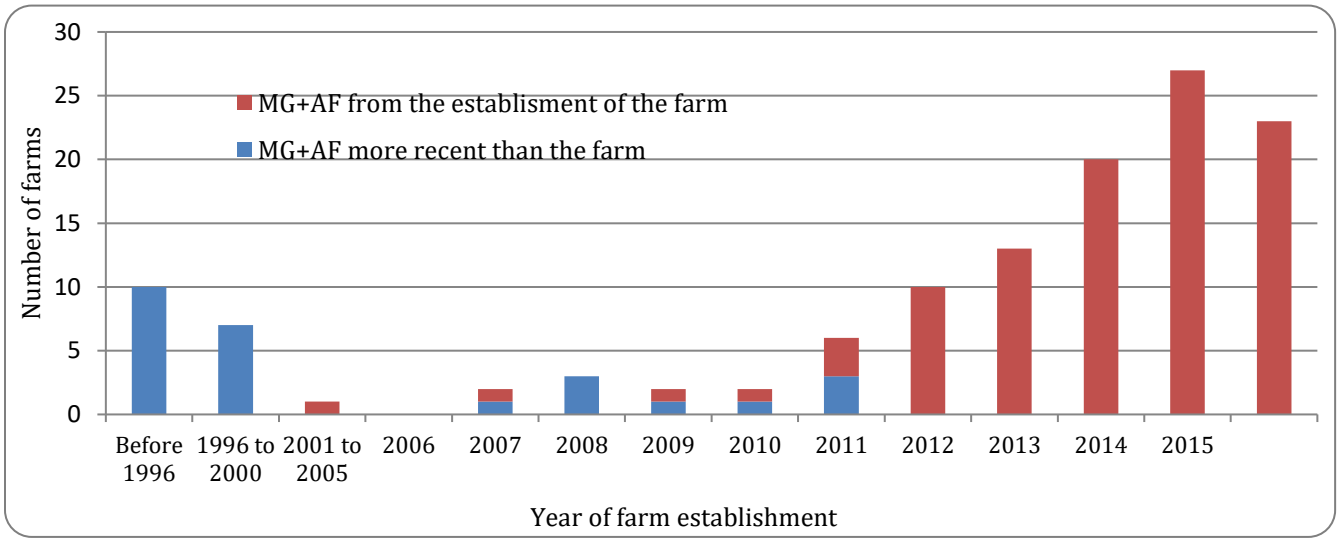

Figure 1. Year of farm establishment and appearance of market gardening agroforestry (MG+AF) on the farm (126 online answers).

Almost all of the most recent farms had a project of agroforestry market since their creation. This project was sometimes carried out in old orchards. Most often, trees were planted at the time of establishment, at least on a significant part of the available space, or very soon after (Figure 1). For the older 30 farms that existed before 2010, the intercropping of trees and market gardening was developed more recently, years after farm creation. Only seven of them have had agroforestry plots for more than six years. Market gardening agroforestry is thus a recent activity, at least in our sample. This has obviously caused the research group problems in choosing the farms with which to continue the work. There was no shortage of farmers willing to participate in a further survey and data collection to ensure geographical representativeness covering the diversity of bioclimatic situations (Figure 2). Nevertheless, the study of the interactions and their effects on the economics and labour organization of the farm had to make sense. It was therefore necessary to study cases of systems that had been in place long enough to be able to observe these effects: the shade of a of three years old tree certainly does not have the same effect on vegetables planted nearby as that of twenty years old one. Unfortunately, there was no choice but to study relatively young agroforestry plots: in 80% of cases, the data presented and discussed below correspond to farms where agroforestry market gardening plots were less than eight years old.

Figure 2. Location of farms involved in the survey.

Survey: The work with volunteer farmers had five main objectives: (i) Describing the agroforestry plots; (ii) Describing the farm structure and the profiles of people involved in market gardening agroforestry; (iii) Characterising the farmers' motivations; (iv) Assessing the impacts of agroforestry on practices, work, economy, ecological functioning and social well-being; (v) Identifying the points of vigilance and recommendations produced by farmers' experience. The survey that was run in 2015 and 2016 covered all these different points (for details see http://www.agroforesterie.fr/SMART/cartographie_SMART/smart-cartographie-des-projets.php). It was organised in several independent parts, requiring a more or less important participation of farmers. Measurements of the impact of trees on vegetable production as a function of distance to trees and biodiversity in agroforestry plots have been carried out on some farms, including four farms undergoing in-depth monitoring, in each of the main regions represented in the responses to online questionnaires, for which precise data were collected on practices and corresponding yields. However, the data were sparse and highly heterogeneous between farms. This article will focus on the analysis of more robust and homogeneous data collected through 3 distinct sub-surveys: (i) Description of agroforestry plots and discussion of their productive and environmental advantages and disadvantages (31 farms); (ii) Description of the farm, discussion of the role of agroforestry in the overall strategy and its impact on economic, labour, organisational and social dimensions (26 farms); (iii) Collection of workload data (19 farms). In the sub-surveys (i) and (ii), questions were asked in order to distinguish the impact of diversification at the farm level (growing fruit and vegetables on the same farm, 14 questions) and of spatial intercropping as such (28 questions). Surveys were carried out by asking farmers to express their agreement with a number of assertions. Following their choice (yes / no / do not know or neutral), they were asked to freely explain the reason. For information about strategic concerns, they were also asked whether this issue was, in their view, of little importance (1); important (2); central (3) from an economic, social and ecological point of view. The manifestation of the agreement (Yes = +1; No = -1; Don't know or neutral = 0) was weighted for the analysis by this note of importance in these different fields.

RESULTS AND DISCUSSION

Market gardening agroforestry: a pragmatic choice for a life project linked to nature: The results presented below take into account only the 26 farms for

which information on the farm and its operation was available. The cultivated acreage of market gardening agroforestry plots of these farms were generally small: 1.3 ha on average. They represented a significant proportion (63% on average) of the total cultivated area. Our sample was in line with the high proportion of small farms, already reported through the broader online questionnaires. The largest proportion of farmers (73%) had no family land inheritance. Given the difficulty in finding land, they turned to market gardening, which can be economically viable on small areas, especially if products are sold through short supply chains. This choice also reflected the "life project" dimension of agricultural activity for these people. They intended to be as autonomous as possible since market gardening required little investment and allowed them to remain relatively independent of financial institutions. They prefered to regain a link with nature as small-scale market gardening involved a great deal of manual labour, in direct contact with the soil. Agroforestry extended these ideas of reconnection with nature and autonomy. Integrating trees into the agricultural space aimed to reproduce the structure and functioning of a natural ecosystem. These strong references to ecology can be related to the urban origin and the high level of education of these farmers (84% had a high school degree, 53% a bachelor's degree or more).

Integrating agroforestry at the establishment of the farm: All the farms in our sample combined vegetable and fruit crops. Fruit species depended on the region in 63% of the cases, the trees were planted within the two years of the farm start-up. In 21%, pre-existing orchards were cultivated in market gardening from the first year of the farm.

Agroforestry was thus an integral part of the farmers' project as soon as they settled in 85% of cases (Figure 3). This did not mean, however, that the organisation of the agroforestry system had been fully planned from the outset. The initial design was applied strictly and quickly in only 45% of cases. On the other farms, it underwent more or less substantial changes. For many of the farmers, these adaptations were opportunistic. The purchase of fruit tree seedlings involved considerable expenditure for farms that did not have substantial financial resources. Even if 8 farmers out of 26 received a small financial support for planting trees from associations, charities or local public institutions, farmers made generally use of what they found at the best price, even if it meant giving up certain species or varieties.

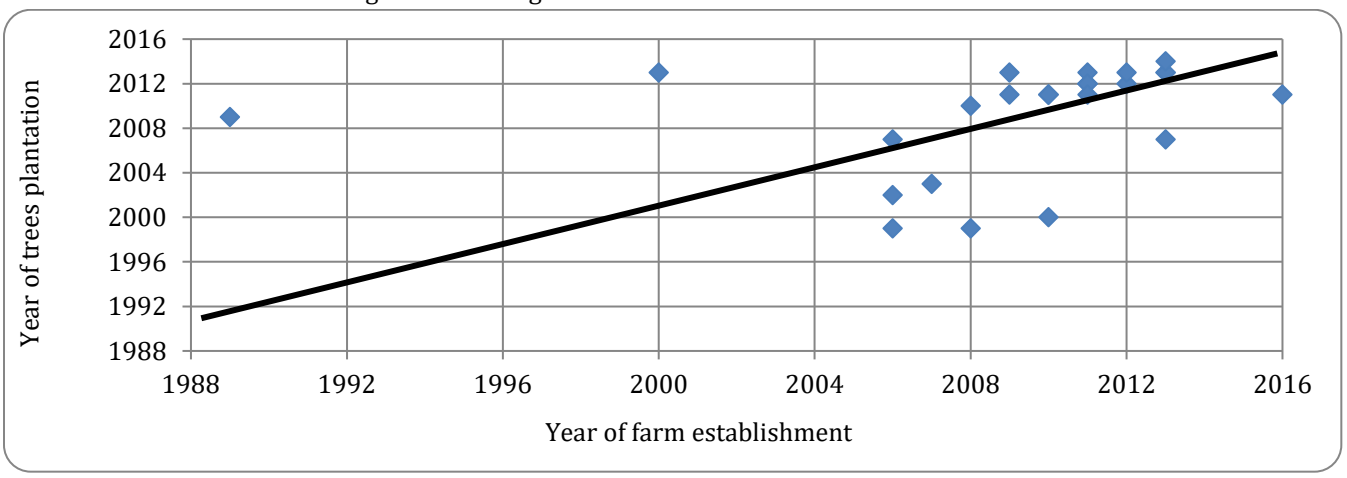

Figure 3. Fruit tree planting in the history of farms (survey completed for 26 farms).

A strategic choice with strong socio-economic impacts: Among the statements proposed to farmers in the survey, the most widely supported were those concerning economic and social dimensions (Figure 4). Growing fruit and vegetables allowed farmers to split the risks of bad harvest between more crops, diversify their commercial offer and respond more fully to consumer expectations. Fruits were often considered as appealing products which made easier to sell vegetables (e.g. in a vegetable-fruit box). This also allowed a better distribution of supply over time. Some fruits (particularly apples) can be kept for a long time without great difficulty. Others can be easily processed (preserves, juices) by farmers or customers. This broadening of product-range contributed to customer loyalty in short supply chains where trust is based not only on objective

criteria (product quality, diversity of supply, etc.) but also on more subjective one (practices demonstrating shared values, particularly regarding the control of environmental impacts and health safety, often associated with organic production). In this respect, farmers considered that agroforestry was well received and contributed to strengthening consumer support for the farm project, which in turn strengthened it.

Overall, the economic impact of agroforestry was positive even if planting trees required extra investment compared to more classic market gardening. However, the economic advantages above-mentioned were not related to intercropping fruit trees and vegetables as such but to product diversification at the farm level. Even if economic advantages of agroforestry were numerous as far as marketing strategy was concerned, it was not possible in the SMART project to analyse in which extent agroforestry quantitatively impacted incomes (little accounting data available, high diversity of contexts and situations, young trees with still low production levels).

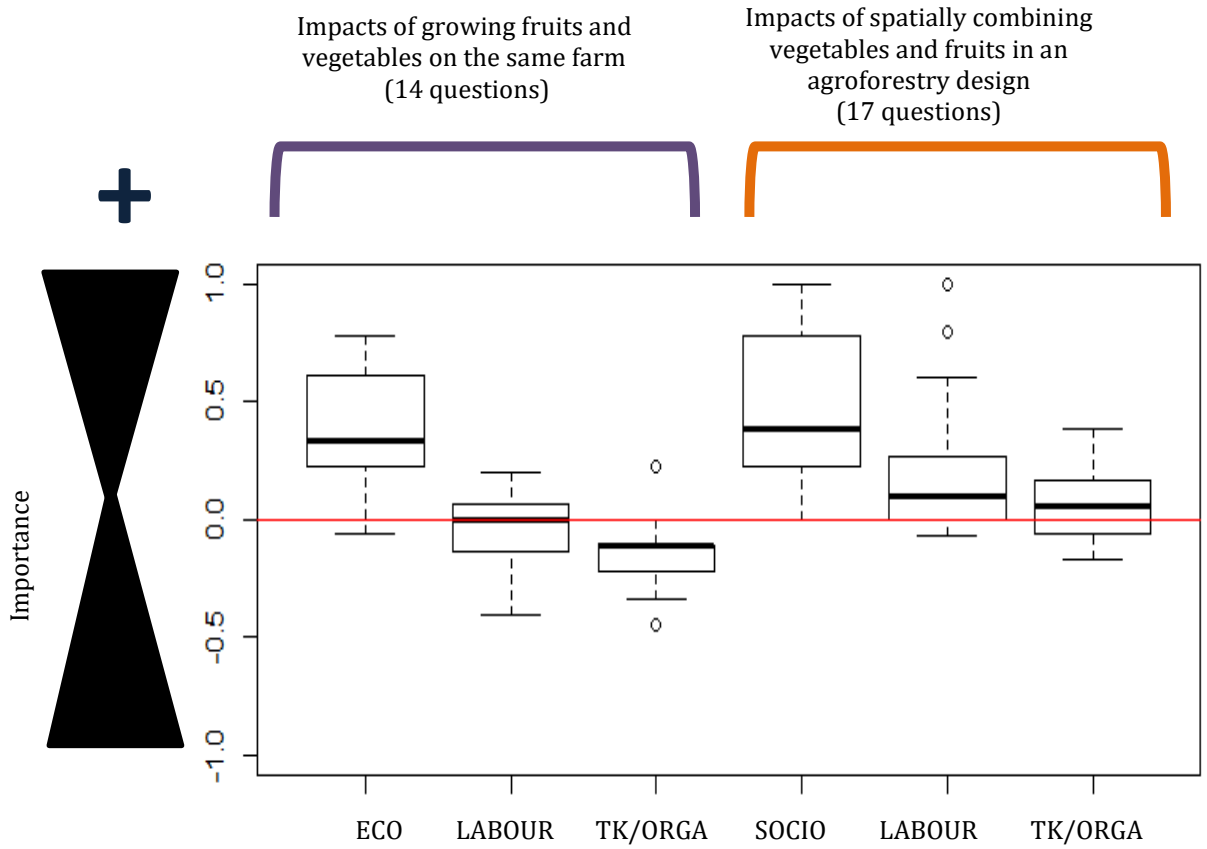

Figure 4. Impacts of growing fruit trees and vegetables on the farm and on intercropping them in an agroforestry design on economic (ECO), labour, technical/organisational (TK/ORGA), sociological (SOCIO) dimensions of the farming system. A scoring higher than 0 means that the impact is positive. The higher the absolute value of scoring, the more the impact (positive or negative) was judged important (survey completed for 26 farms).

In terms of social benefits, agroforestry, as an innovative form of agriculture with strong values, brought together dense networks of practitioners and supporters. Farmers mentioned that intercropping trees with legumes created a beautiful landscape that attracted many people on the farm (visitors, volunteers, trainees). Such human presence was a resource for the economy of the farm (customers, free workload in exchange of training) while bringing a sense of meaning and satisfaction to farmers (feeling useful in contributing to build a more sustainable society, sharing knowledge etc.).

The feeling of participating in an informal collective project to transform the forms of agricultural production and the relations between producers and consumers was widely shared by farmers. The success of the SMART online survey could be a further indication of this

affection to agroforestry. Nevertheless, it must be noted that this collective existed primarily via Internet and social networks. In practice, only a small minority of farmers received system design support from more experienced neighbours or structural technicians promoting agroforestry. Isolation in at the local level remained a major disadvantage for those who demand pioneering approaches.

Impact on labour and organisation: Market gardening agroforestry was judged responsible for constraints on workload and working conditions. Detailed workload information showed some complementarity during the winter months between tasks dedicated to trees and to vegetables (Figure 5). However, the workload that had to be devoted to trees at the end of spring and summer was sometimes superimposed on the main peak in market gardening, especially for farmers whose trees had come into production. The heavy workload caused by this overlapping was considered as risky because it could lead farmers to neglect critical interventions on trees. To limit this risk farmers raised the issue of choosing adapted species and varieties of fruit trees which required less work during the vegetable peaks workload.

The fact of having to do several jobs (arboriculturist and market gardener) was ambivalent. On one hand, it made possible to do a less repetitive labour, even in the gestures to be accomplished and thus to be less physically painful. On the other hand, it increased the skills required and the complexity of managing very different productions. Most important labour and complexity constraints were related to production diversification (tension between activities) at the farm level rather than to spatial intercropping as such. Intercropping of trees and legumes was sometimes said to increase management complexity, e.g. difficulties in pruning trees without damaging vegetables, mechanised intervention with tractor on vegetables complicated by trees. Most farmers insisted on the fact that such spatial issues could be partially or totally avoided at designing the system if enough distance was planned between rows of trees and between rows of trees and vegetables beds. Unfortunately, not all farmers had initially considered these issues.

Despite this possible complexity, spatial combination had rather positive effects on labour and organisation (Figure 4). Working in a plot with trees and vegetables helped farmers to always have an eye on both crops which eased management and allowed farmers to be more reactive in some critical interventions. A majority of farmers considered that intercropping of vegetables and trees offered them a better quality of work. It was more pleasant to work in the shade and trees allowed to break the wind. The presence of trees offered an aesthetically pleasing working environment which echoed the wish of these new farmers to (re)create strong links with nature. The feeling that agroforestry contributed to a higher biodiversity connected to the observation or more birds and insects (see next part) also played a major role in creating a positive atmosphere. Although farmers highlighted that an increase in workload and complexity was not to be neglected, the benefits brought by agroforestry resulted in most farmers considering agroforestry as rather favourable in terms of work.

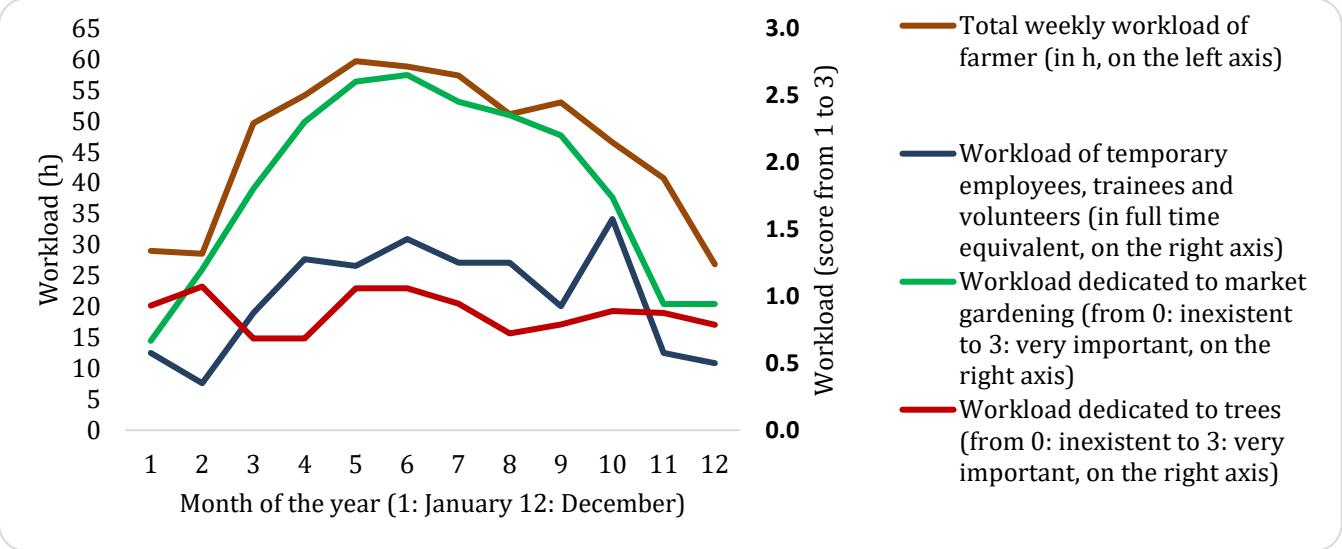

Figure 5. Average workload over the year (survey completed for 19 farms).

Productive and environmental impacts: Overall, a significant proportion of market gardeners did not state a very sure opinion on the impacts of agroforestry on productivity and the environment (Figure 6).

However, the answers to the assertions concerning the productive advantages and disadvantages of market gardening agroforestry showed contrasting results (Table 1). Most farmers considered that trees did not affect the essential eco-physiological factors of vegetable productivity (lighting, water supply). In terms of ecological functioning and environmental impact, the major benefit was a higher perceived level of biodiversity and the possibility to optimise space and reducing land use footprint with the spatial intensification allowed by agroforestery. Farmers had no certainty about (i) a possible negative impact on the productivity of vegetables that could be produced by the agroforestry system, (ii) on the overall benefit of associated crops compared to pure crops or (iii) on the impact on the distance between cultivated vegetables and trees on their respective productivity.

The productivity measurements that were carried out in relation to distance to trees showed the results were too variable, depending on soil type, climate, and crops, to draw robust conclusions. Farmers also were quite uncertain on the impact of agroforestry on diseases, pests and water use. However, some of them mentioned that trees could help to naturally recycle nutrients in the agroecosystem with fallen leaves and then impacting fertility.

Table 1. Answers to assertions about the productive and ecological advantages and disadvantages of market gardening agroforestry (Survey completed for 31 farms; letters indicate significant differences at 0.1 level for post-hoc pairwise chi-square tests carried out with the R-package rcompanion))

Dimension	Assertion	I don't know	No	Yes
Productive	Trees has a negative effect on germination and the beginning of growth of vegetables	39%[a]	57%[a]	4%[b]
	Trees cause harmful hydric competition with vegetables	25%[a]	75%[b]	0%[c]
	Shade of trees hinders market gardening crops	25%[a]	50%[a]	25%[a]
	The quality of harvested vegetables is better in agroforestry plots	64%[a]	14%[b]	21%[b]
	Productivity of vegetables is lower in agroforestry plots	41%[a]	33%[a]	26%[a]
	The impact of trees on vegetables is stronger on the vegetables in their proximity	36%[a]	32%[a]	32%[a]
	The overall productivity of the intercropped plots makes them more interesting than separated pure crops	33%[a]	19%[a]	48%[a]
Environmental	Biodiversity (birds, insects) is higher in agroforestry plots	18%[a]	11%[a]	71%[b]
	The impact of diseases and pests on trees is lower in agroforestry plots (lower inputs)	54%[a]	14%[b]	32%[ab]
	The impact of diseases and pests on vegetables is lower in agroforestry plots (lower inputs)	57%[a]	18%[b]	25%[b]
	Agroforestry allows to save space (land use)	15%[a]	15%[a]	70%[b]
	Agroforestry impacts irrigation practices (water use)	37%[a]	32%[a]	32%[a]
	Agroforestry impacts fertilisation practices (lower inputs)	20%[a]	35%[a]	45%[a]

Developing knowledge for complex but enjoyable practices: Although the major uncertainties of farmers about agroforestry were related to its environmental and productive impacts, the survey also highlighted doubts and knowledge gaps on other dimensions (Figure 6). The farmers' high degree of uncertainty about the different assertions of the survey was certainly rooted in the fact that their experiences were often recent. For farmers who had set up their agroforestry plots only a few years ago, the answers to the questions shed light on the a priori reasons for agroforestry choice. The experience gained was not yet sufficient for them to confirm or not the validity of this hypothesis. In many of these farms, the trees had not yet fully developed. It is

therefore conceivable that negative effects, linked for example to the shade effect of trees on vegetables, had not yet emerged.

It should be noted that farmers with more extensive experience generally had a clearer opinion on certain subjects proving that some difficulties of agroforestry are maybe underestimated by new practitioners. For example, more advanced farmers considered more often that trees could disrupt vegetable growth and production, were more aware of the challenges of handling peaks workload for trees and vegetables in the same time (Figure 7) and advised to be very careful with distance between trees and vegetables in order not to make interventions on trees or vegetables more complicated.

This advocates for experience exchanges between more advanced and new agroforestry practitioners which is all the more crucial for innovative practices lacking stabilised knowledge. During the interviews, more experienced Normandy farmers acknowledging competition between trees and vegetables told us that they were not considering abandoning market gardening agroforestry but modifying their choice of species in the sectors most exposed to potential competition from trees, choosing plants less sensitive to this competition to cultivate in their immediate proximity, or even substituting annual crops with fruit bushes (raspberries, etc.).

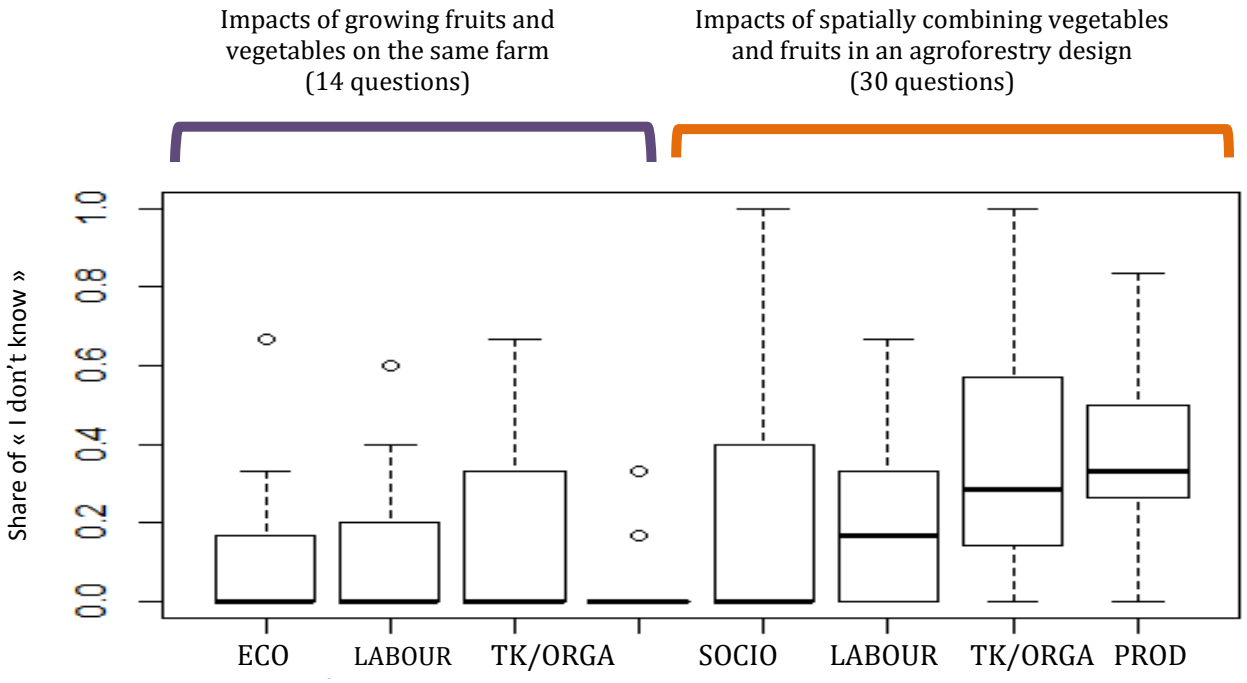

Figure 6. Share of "I don't know answers" across farmers about the impacts of growing fruit trees and vegetables on the farm and of intercropping them in an agroforestry design on economic (ECO), technical/organisational (TK/ORGA), sociological (SOCIO), environmental (ENVIRO) and productive (PROD) dimensions of the farming system (26 surveys completed).

It illustrates that one of the main difficulties of agroforestry systems, observed in other climatic contexts, is to manage the dynamics of this complex architecture over the long term (Kehlenbeck & Maass, 2006) and finding suitable varieties, species and planting densities for efficient agroforestry patterns. For temperate contexts, both scientific and professional literature is unfortunately very rare, especially for trees and vegetables intercropping, even is some recent projects have collected useful information (e.g. the AGFORWARD European project, (http://www.agforward.eu). Such questions remained essential for the farmers involved in the SMART project. Many wondered about the medium and long-term consequences of the density of tree planting that they initially chose. Would they have to sacrifice certain trees to maintain market garden productivity?

Whatever their doubts, most farmers (20 out of 26) would recommend market gardening agroforestry to people wishing to set up a market gardening farm even if some of them mentioned conditions for that such as strong interest for ecological management (5) or not

having too many economic expectations (2). Out of 24 farmers who answered the question whether they were globally satisfied of market gardening agroforestry, 15 answered "yes", 2 "no", 4 "not yet" and 3 "not enough distance to make a judgement". A very large majority of them considered that they would choose the intercropping with trees if they had to set up another market gardening plot. Agroforestry corresponded indeed to their needs for diversified production to meet the demands of consumers with whom they were in direct contact. It was also fully in line with their personal project to develop an ecologically diverse system whose functioning was as close as possible to natural ecosystems guaranteeing resilience and autonomy.

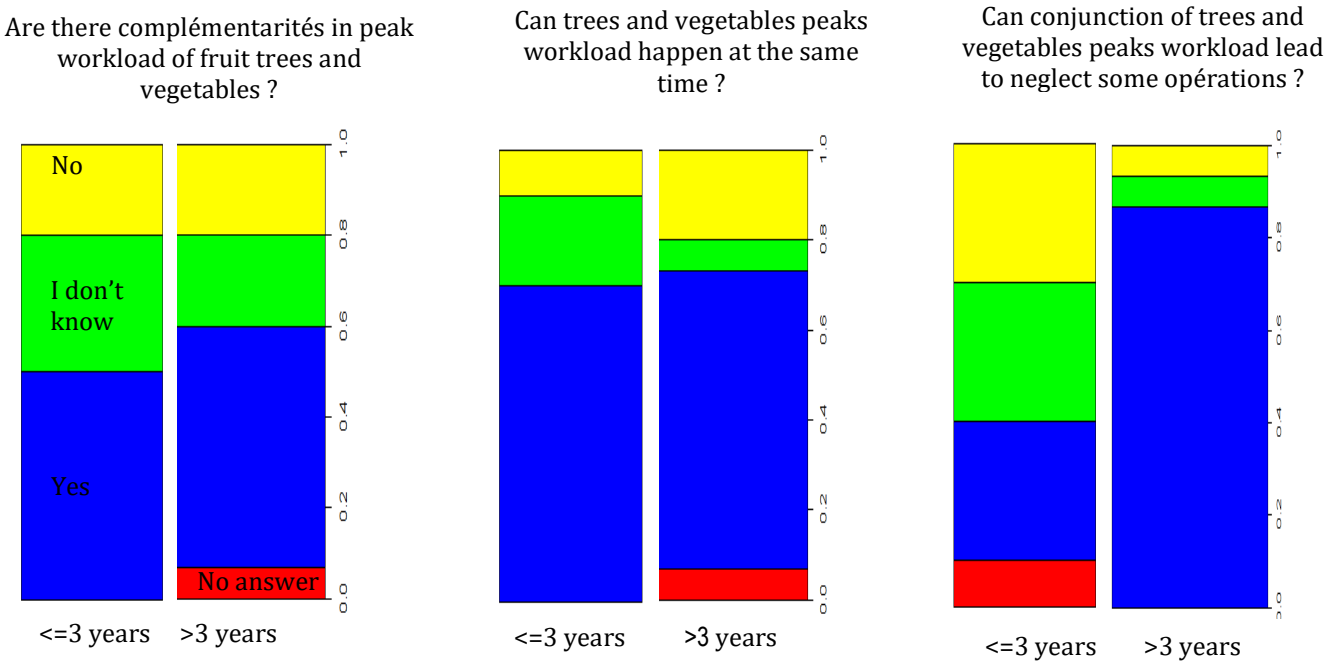

Figure 7. Evolution of farmers' answers to 3 questions dealing with trees and vegetables peaks workload according to age of trees plantation (26 answers).

CONCLUSION

For the first time in France, the SMART research programme explored market gardening agroforestry systems. These, which were still extremely rare at the beginning of this century, are currently undergoing a strong development, in line with the current trend of establishment of small organic farms, generally created by people without any previous family farming ties. The survey work carried out among farmers led to a better understanding of the determinants of their choice of this type of practice. It showed that integrating agroforestry was part of a life project and involved socio-economic, organisational, labour, agronomic and environmental dimensions, which advocates for a holistic approach to agroforestry integration in farming systems design. However, the relative youthfulness of these experiences did not yet allow a reliable assessment to be made of the performance, advantages and disadvantages of market gardening agroforestry. In order to achieve this, the work undertaken should be pursued through longer-term monitoring, in close cooperation with the farmers concerned. A key issue that needs to be addressed is the dynamics of these systems and the adaptive management that needs to be adopted to take into account the structural and functional changes they are undergoing over time. This question is all the more difficult as these agroforestry systems are extremely diverse in their spatial organisation and in the diversity of cultivated species they manage, annuals, perennials, bushes and trees. Each situation thus appears radically unique. It would probably be meaningless to infer directly reproducible recommendations from their study. Rather, the nature of scientific knowledge to be generated should focus on identifying design and conduct principles that can be used to guide efforts to improve existing systems and enable new project developers to take full advantage of the experience gained by these pioneers. The interest of the study of

these agroforestry market gardening systems lies also in its heuristic value for reflection on the production of and the knowledge of practitioners. Market gardening agroforestry seems to us to be a particularly fruitful model for thinking about the agro-ecological design of agricultural systems, valuing ecosystem services while ensuring their reproduction, thus guaranteeing the sustainability and resilience of these systems.

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