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Abstract

Over the past fifteen years, more and more farmers have been setting up diversified organic market gardening on small area (less than 1.5 ha), while microfarms are complex systems lacking clear technical, economic, and organizational references. The MMBio project aims to establish such references through surveys conducted on 42 microfarms in France. The viability of these microfarms is assessed based on available income (average of €13,894/year/farmer with a standard deviation of €10,058; €6.80/h with a standard deviation of €4.49), demonstrating that this activity can generate an acceptable income. Multivariate analysis of various technical and economic indicators, about diverse farm components, does not reveal a consistent combination of factors directly related to viability or livability. Further analysis of specific dimensions, such as work efficiency and farmers' temporal trajectories could help identify advantageous conditions for viability and livability in micro-scale market gardening.

Keywords: Microfarm, agroecology, market gardening, organic agriculture, economic viability, livability

1. Introduction

The challenges of renewing the farming generation and relocating food production have made their way onto the French political agenda, alongside growing consumer demand for local, high-quality food. At the same time, the profiles of prospective farmers are changing, with more and more of them setting up outside the family (HCF)[1] and working on diversified organic market gardening production systems with a strong focus on the local market (FNAB, 2017; ITAB, 2018; Morel, 2016). These small-scale, diversified organic market-garden micro-farming systems meet the needs of people with no agricultural background (NIMA), limited investment capacity and limited access to land (Barral & Pinaud, 2015).

[1] HCF installations (outside the family) are on the increase, rising from 30% of installations in 2000 to 36% in 2021 (Agreste, 2023).

However, these models raise questions about their ability to be economically viable, because the people behind this type of project face a number of difficulties in setting up: i) difficulties in accessing quality land (access to water resources, type of soil, slope, exposure, etc.); ii) validation of the minimum surface area required for farming; iii) tortuous setting-up procedures involving a number of players of whom the NIMA people are not necessarily aware; iv) funding for setting up; v) difficulties in accessing quality land.); ii) validation of the minimum surface area required for registration[2] ; iii) tortuous set-up procedures involving multiple players of which NIMA people are not necessarily aware; iv) financing of the set-up; v) lack of perspective and references; vi) lack of knowledge of these systems or of NIMA people in support or training structures, but also a desire on the part of some project sponsors to set up independently without recourse to advisory networks; vii) selectivity of the young farmer grant (DJA, the main form of start-up aid) based on age and a commitment to generate an income in excess of the SMIC (Minimum Growth Wage) in the fourth year, which limits the scope for progressive start-ups; viii) difficulties in achieving the expected level of income, difficulties in administrative management, in managing the work/life balance, in production, etc.; viiii) difficulties in achieving the expected level of income, difficulties in achieving the expected level of income, difficulties in administrative management, in managing the work/life balance, in production, etc.

These difficulties necessarily lead to projects being abandoned (de Lapparent, 2021), although it is not yet possible to quantify this precisely. These difficulties have now been clearly identified by those involved in training and support. Among other things, they are expressing the need to produce technical and economic benchmarks for these systems, which are atypical not only because of the profiles of the men and women who run them. It is also the farming practices used, and above all their size, that call into question the way in which these micro-farms can work towards economic viability. While some authors have noted a negative correlation between surface area and productivity (Carter, 1984; Cornia, 1985), what about viability in the sense of income for the farmer?

Some of those involved in training and support consider that a diversified organic market gardening project is unrealistic if it involves less than 1.5 ha of land under cultivation. Others believe that active microfarms subsist mainly on their training and advisory activities. But field surveys have shown that small farms of less than 1.5 ha can be viable (Bourrely & Berry, 2017; Declerq and Clerc, 2011; Drouet, 2010; Morel, 2016), and a thesis concluded that economic viability is possible on these systems, especially if the techniques and strategies are adapted to the small-scale model (Morel, 2016).

Against this backdrop, the CASDAR MMBio (Microfermes Maraîchères Biologiques) project aimed to acquire, consolidate and disseminate technical and economic benchmarks for diversified organic market-garden microfarm systems. Twenty-four partner organisations from agricultural education, development, the organic network and the Chambers of Agriculture, as well as those involved in research and experimentation, worked in three areas: i) characterisation of these MMBio systems on the basis of multi-year surveys, ii) on-station experimentation with so-called intensification practices (fertilisation, density and crop associations), and iii) promotion of the project's contributions with the production of tools and technical manuals for a wide audience (trainers, advisers, research, project leaders, farmers, local authorities).

Here we focus on the first area of the project and attempt to answer the following question: to what extent can organic and diversified market garden micro-farms be economically viable, and what factors can be associated with viability and sustainability? We propose to answer this question by analysing data from

[2] The social status of farm manager is dependent on the AMA (minimum liable area), which comprises three non-cumulative criteria. The AMA is set by prefectoral decree for each département and for each type of crop. It can vary threefold for market gardening, depending on the department, and sometimes exceeds 1 hectare, even though some market gardeners set up on less than 1 hectare. If the SMA is not achieved, the working time devoted to farming must be at least 1,200 hours a year (including packaging, processing and marketing time). Finally, if these criteria are not met, the professional income generated by the farming activity must be at least equivalent to 800 SMIC per hour.

surveys carried out as part of the MMBio project. Viability (the economic dimension) and livability (the social dimension) are complex concepts involving many factors. We approach the former through disposable income, and the latter through indicators of satisfaction and hardship (see section 2.3.2). We begin by characterising the viability of these microfarms in terms of the disposable income generated by market gardening alone. We then use multivariate descriptive analyses to attempt to identify viability or sustainability factors based on technical and economic indicators (Rivière, 2023).

2. Materials and methods

2.1 Data acquisition

A sample of 42 MMBio farms in mainland France was selected from the partner networks. The selection criteria were as follows: professional farm, at least three years in business, available accounts, area under organic market gardening of less than 1.5 ha, at least two-thirds of turnover from market gardening. Surveys will be carried out between 2019 and 2022, covering a wide range of topics: surface area, labour, work organisation, farming practices, equipment, investment, marketing, networks and sources of information, drudgery, and satisfaction with various items. In order to produce technical and economic benchmarks specific to small-scale diversified organic market gardening, all the information gathered relates to the market gardening activity only, although **60% of the farms in the panel have at least one other production workshop on the farm.** An accounting reconstruction exercise was carried out using a dedicated tool, so as to collect and compare only economic indicators (turnover, costs, income, etc.) specific to market gardening. In the end, 38 farms with usable accounts were included in the panel (Rivière, 2023).

2.2 Choice of viability indicators for an organic vegetable microfarm

We assume that **the annual disposable income per market gardener is an indicator for assessing the viability of a microfarm**. An increase in this income gives the market gardener a capacity for self-financing and enables him to meet his needs, thus guaranteeing the sustainability of the activity (Morel, 2016). **Hourly income** is the second indicator that extends the context for assessing the viability of microfarms.

We also hypothesize that the following parameters influence the viability of these microfarms (Rivière, 2023):

- The **proportion of surface area cultivated under cover**, shelters, greenhouses and vegetable tunnels enabling the cultivation of high value-added species and the extension of productive periods (Galinato & Miles, 2013; Perkus, 2018);
- The **area utilisation coefficient**, with the multiplication of crop cycles leading to greater productivity of cultivated areas (Morel, 2016);
- **Labour intensity**, i.e. the number of hours worked per unit of developed area. Comparing labour intensity with area productivity can tell us something about the market gardener's efficiency, and therefore his ability to generate a given level of income per unit of time;
- The **proportion of working time allocated to marketing**, because while marketing gives concrete expression to the efforts and resources that have been allocated to the preparation, production and harvesting of vegetables, the time spent on this activity remains non-productive and must be minimised in order to preserve marketing efficiency (Bourrely & Berry, 2017) ;
- **Selling prices**, because high prices make it easier to sell the produce but may limit the number of buyers, whereas low prices make it easier to sell the produce but may not be enough to generate sufficient income or even cover production costs. Setting selling prices not only depends on the goodwill of the market gardener, but is also highly dependent on the consumer area (standard of living of the clientele, average willingness to pay, competition);

- The proportion of turnover generated by a given type of sales channel reflects the degree of **concentration/dispersion of sales**, and therefore of the associated working time. A high degree of concentration of turnover on a particular sales channel indicates a certain degree of commercial efficiency;
- **Investment** allows us to equip ourselves with appropriate and efficient production tools, but the recourse to borrowing, which is often used to finance it, puts financial pressure on the farm, which can jeopardise its viability;
- The **timing of investments**, or their distribution over time from the installation phase. Investing in a complete production facility at the start-up phase, *especially* for a mechanised system, allows you to get your business off to a flying start, but requires you to generate enough turnover quickly to pay off any annual repayments, which will put a corresponding strain on disposable income in the first few years. Conversely, a progressive investment strategy means a more moderate start to the business, but less pressure from the need to repay large loans;
- **Farming practices**, because although different farm strategies and organisations should probably lead to similar economic results (Amato-Delavoipierre, 2019), the specific features of our subject of study (great diversity of crops, limited surface area) lead us to wonder whether certain practices are not more 'profitable' than others.

2.3 Approach and data analysis

Once viability has been characterised on the basis of the two income indicators (annual and hourly), the approach consists of (i) synthesising the available information on farming practices (yes/no type), by constructing groups of farms with similar practices; then (ii) adding these groups as a new variable to the rest of the technico-economic indicators (identified in section 2.2) in order to identify factors or combinations of factors that are favourable or unfavourable to viability (Rivière, 2023).

2.3.1 Factor analysis and hierarchical ascending classification to identify groups of farms with similar practices

Before seeking to identify success factors among the technical and economic indicators, it is necessary to summarise information about farming practices.

The surveys revealed whether or not market gardeners adopted various practices relating to (i) tillage, (ii) pest management, (iii) fertilisation and (iv) the multiplication of crop cycles (Table 1). The variables used are both quantitative and qualitative. In addition, our sample size was too small for a multiple correspondence analysis (MCA), integrating the previously discretised quantitative variables, to be relevant (Escofier & Pagès, 2008). For these two reasons, we carried out a **mixed data factor analysis** (MDFA). This method combines the principles of principal component analysis (PCA) for quantitative variables and MCA for qualitative variables (Escofier & Pagès, 2008). Next, a **hierarchical ascending classification** (HAC) using Ward's method is applied to the first X principal components from the AFDM. The advantage of retaining only the first principal components is that the groups can be constructed by reducing the noise inherent in the last principal components, which explain very little of the variance (Husson et al., 2010). These analyses resulted in three groups of practices (Rivière, 2023).

Table 1: Variables used to identify groups of farms with similar practices

PRACTICES			
Qualitative variables	**Yes**	**No**	**NC*.**
Systematic fertilising	14	26	2
Use of commercial fertilisers	22	19	1
Mechanical weeding	23	16	3
Plastic mulch	32	8	2
Organic mulch	24	17	1

Thermal weeding	20	21	1
Occultation	29	12	1
Ploughing	6	36	0
Plant protection products	30	12	0
Biological control	19	21	2
Alternative techniques (plant extracts, purins, others)	22	18	2
Anti-insect netting	37	4	1
Quantitative variables	**Means.**	**Med.**	**Standard deviation**
Average tillage depth (cm)	15,67	18,00	10,87
Land use coefficient	1,63	1,57	0,38

***NC:** Not communicated

2.3.2 *Factor analysis to identify success factors*

An AFDM is carried out for the same reasons as those relating to the AFDM linked to practices, in order to identify any combinations of factors favourable to viability. It includes the **active variables** presented in Table 2. It also takes into account **eight illustrative variables**: (i) disposable income per hour, (ii) annual disposable income per market gardener, (iii) turnover per m², (iv) costs per m², (v) annual payments, (vi) satisfaction with quality of life, expressed on an increasing scale from 0 to 4, (vii) satisfaction with consistency with the market gardener's values expressed on an increasing scale from 0 to 4, and (viii) overall hardship (average of hardships felt on an increasing scale from 0 to 4 in relation to four items: technical complexity, mental difficulty, physical difficulty, feeling of work overload).

These illustrative variables serve to broaden the context of interpretation (Escofier & Pagès, 2008). In our case, they characterise the **viability** (economic indicators) and **liveability** (hardship and satisfaction) of the activity on the farms. **The aim is to understand whether these variables are correlated with one or more of the principal components calculated by the AFDM. In so doing, we seek to identify which of our technico-economic indicators may or may not contribute to the viability and liveability of microfarms** (Rivière, 2023).

Table 2: Technical and economic indicators used in the factorial analysis to identify success factors

INDICATORS			
Qualitative variables	**1**	**2**	**3**
Timing of investments	9	17	15
Practice groups** (in French)	13	23	6
Quantitative variables	**Means.**	**Med.**	**Standard deviation**
Land use coefficient	1,63	1,57	0,38
Percentage of area cultivated under shelter	16,8%	15,8 %	10,0 %
Hourly volume / 1000 m² developed	348	341	143
Percentage of hours allocated to marketing	18%	16%	8%
Share of sales on the main circuit type	74%	70%	20%
Average price differential*** (%)	0,00	-0,01	0,12
Total amount invested since setting up (excluding land, market gardening only)	56 930	53 215	28 521

** The timing of investments is noted as 1 if the investments were mainly made during the installation phase, 3 if they were made gradually (between installation and the survey), and 2 in the case of an intermediate strategy.*
*** Practice group 1 includes farms using "conservation agriculture", group 2 includes farms using "biointensive" practices, and group 3 includes farms using "conventional" practices (see section 3.2).*

**** An average selling price per species (tomato, heirloom tomato, salad, mesclun, spinach, courgette, cabbage, bean, pumpkin, carrot, ware carrot, early potato, ware potato) was calculated for the farm panel. Percentage deviations from this average selling price per species were calculated for each farm, which were then integrated to construct an average price deviation per farm.*

All these operations were carried out using R software (version 4.2.2), under the RStudio environment (version 2022.12.03). The packages used are missMDA, version 1.18 (Josse & Husson, 2016) for managing missing data and FactoMineR, version 2.7 (Lê et al., 2008) for multivariate analysis and classification.

3. Results

3.1 An organic vegetable micro-farm can be viable

The income generated per market gardener varies from **-€12,441**[3] **to €46,700** (Figure 1a), **with an average of around €14,000** and a **median of almost €12,000**[4] . 45% of farms generate an income per market gardener higher than the net minimum wage in 2020.

Income per hour worked by market gardeners (Figure 1b) varies from **€3.51/hour**[3] **to €18.92/hour, with an average of €7/hour** and a **median of €6.13/hour**[4] . 37% of farms earn more per hour than the net minimum wage in 2020.

The minimum wage should be seen as a benchmark, not an absolute threshold of viability. Some market gardeners are satisfied with incomes below the minimum wage, while for others the minimum wage is not enough to meet their needs. Nevertheless, there is considerable variability in income from farm to farm, and this variability includes income levels that show that viability is possible in organic and diversified market gardening on a small area (Rivière, 2023).

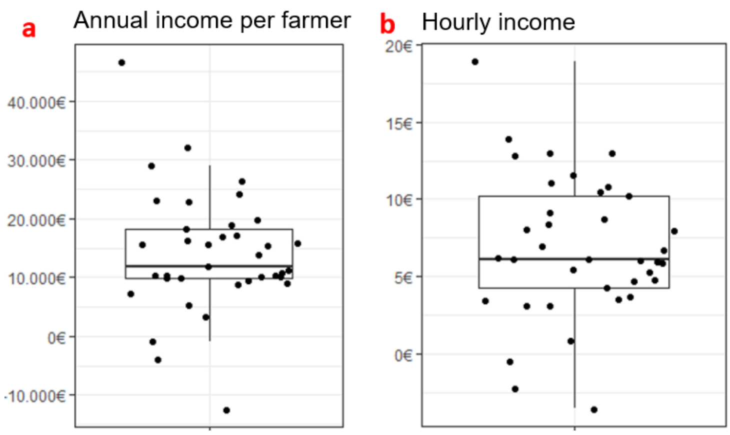

Figure 1: (a) Annual income per market gardener. (b) Hourly income generated by the market gardening activity. The vertical bars represent quartiles 1 and 4, the box represents quartiles 2 and 3 separated by a horizontal bar (the median).

3.2 Characterisation of farming practices

The proportion of inertia contained in the principal components decreases **steadily** after the third component (Figure 2a), suggesting limited interest in interpreting them (Escofier & Pagès, 2008). The first three components account for 43.5% of total inertia. The statistical noise that can be assumed beyond the first three components arises from the fact that **the combinations of practices are, in reality, almost**

[3] Negative income is explained by loan repayments in excess of EBITDA.

[4] The net annual SMIC in 2020 was €14,623, and the net hourly SMIC was €8.03 (in France, INSEE, 2023).

unlimited. Our attempt at grouping cannot therefore result in groups of farms that are significantly different from the point of view of all the practices. Only the most discriminating practices will contribute to the construction of groups (Rivière, 2023).

Three groups of farms with similar practices emerged from the classification based on the first 5 principal components of the AFDM, representing 61% of the total inertia (Figure 2b).

Group 1 (14 farms) adopts practices that can be described as **conservation agriculture**[5] , focusing on the prevention of bio-aggressors and non-intervention in the soil except to fertilise and/or amend, with a preference for the use of local resources: preventive strategy (crop associations and rotations, organic mulching, netting, shading), no mechanical weeding or use of plant protection products, no systematic fertilisation or use of commercial fertilising products, no tillage, etc. The median coefficient of intensification for these farms is 2. The median area intensification coefficient is 2. These farms are more likely to self-produce their plants and even their seeds.

Group 2 (22 farms) adopts so-called **biointensive** practices aimed at controlling risks: systematic use of commercial fertilisers, tillage between 15 and 20 cm for soil preparation and/or weed management (no ploughing), plastic and/or organic mulches, shading, anti-insect nets, plant protection products sometimes combined with biological control, no crop combinations. The median area utilisation coefficient is 1.52. A large proportion of the group (15 farms out of 22) self-produced at least half of their seedlings, but almost all the farms in the panel that did not produce seedlings were also in this group.

Group 3 (6 farms) uses practices that can be described as '**classic**' in diversified organic market gardening, except for disease and pest management: ploughing, mechanical weeding and plastic mulching, 20 cm tillage, preventive strategy for diseases and pests using alternative techniques but using plant protection products if necessary, little systematic fertilisation and commercial fertilisers. The median area utilisation coefficient is 1.51 (equivalent to group 2).

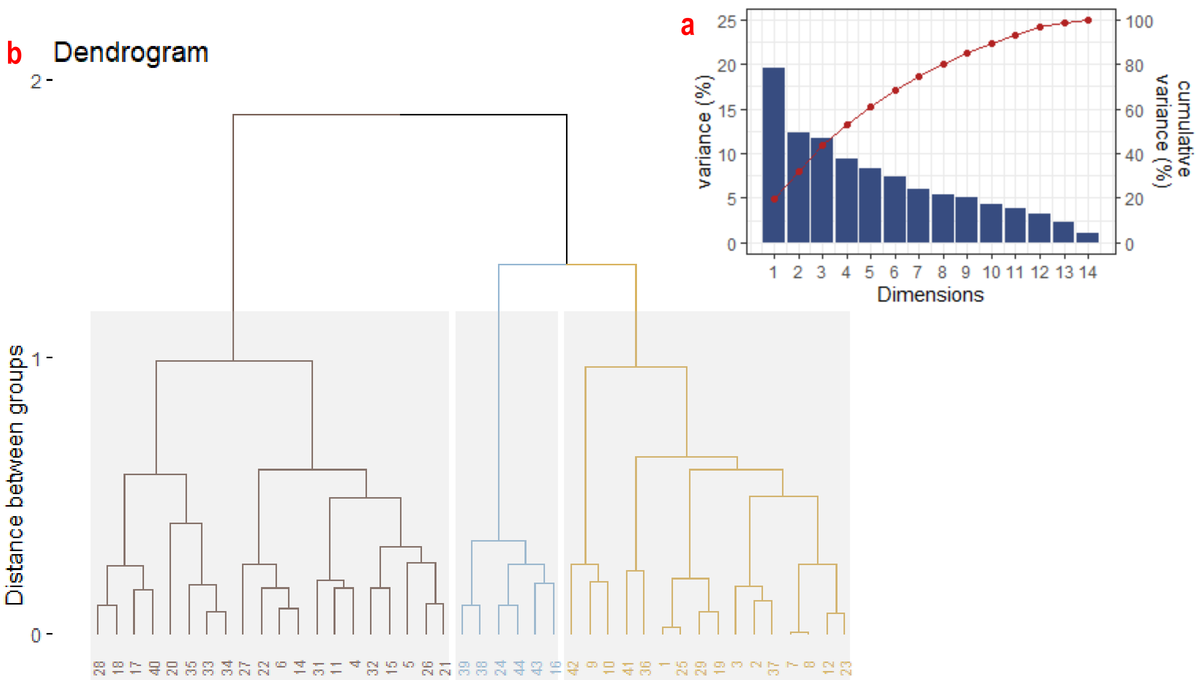

Figure 2: (a.) Share of variance explained by the dimensions of the AFDM on practices. The bars represent the proportion of variance explained by each of the dimensions, and the curve represents their sum. (b.) Hierarchical tree resulting from the AHC performed on the first five dimensions of the AFDM. The numbers correspond to the

[5] The abuse of language which consists in encompassing the practices of these 14 farms within the name of "conservation agriculture" is extremely simplistic and is intended solely to schematise reality. The same applies to the other two groups of practices.

anonymised farms. Each of the three groups is identified by a colour [brown: group 1 (14 farms); blue: group 3 (6 farms); beige: group 2 (22 farms)].

These three groups show **significant internal variability**, in line with the 61% of variance explained by the first five components on which the classification was based, indicating that a practice that is characteristic of one group (e.g. ploughing for group 3) is not necessarily exclusive of another that is characteristic of another group (e.g. organic mulching for group 1). Practices that are 'related' to cultivation methods that are *a priori* different (conservation agriculture *vs.* so-called conventional practices) can sometimes be combined, depending on the way in which each market gardener applies his knowledge, derived from his training and experience, in his soil-climate and socio-economic context (Morel, 2016).

These three groups of practices are added to the multivariate analysis of all the technical and economic indicators.

3.3 Towards identifying success factors?

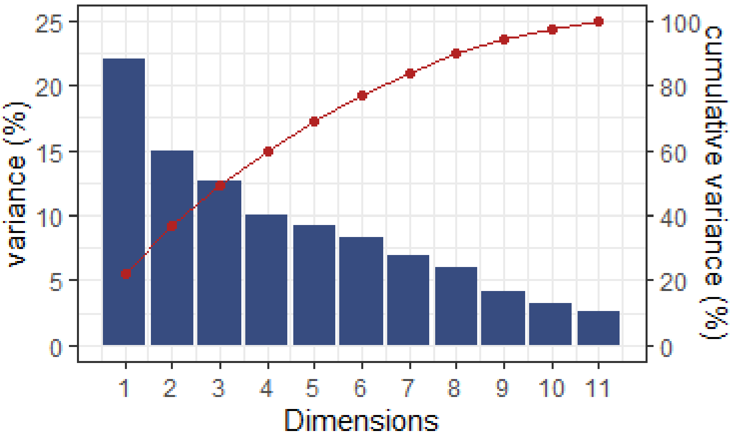

Figure 3: Share of variance explained by the dimensions of the AFDM on the technical-economic indicators. The bars correspond to the share of variance explained by each dimension. The curve represents their accumulation.

As with the AFDM applied to practices, the proportion of variance explained decreases steadily after dimension 3 (Figure 3). We therefore give priority to **interpreting the first three dimensions**, which account for 50% of the total variance. Table 3 shows the coordinates, contribution and quality of representation (cos2) of the variables for the first four dimensions (Rivière, 2023).

3.3.1 Dimension 1: towards intensive use of surfaces

The first axis accounts for 22% of total inertia. It is positively correlated with the proportion of land under cover, the deviation from the average price, the land use coefficient and investment (Table 3). It contrasts (i) farms that intensify the use of their land (more than 20% under cover, at least 1.7 crop cycles per year), that have higher than average selling prices (up to +28%) and that have invested relatively heavily in production equipment (€90,000 on average), (ii) farms that are not very intensive (less than 10% under cover, 1.06 to 1.79 crop cycles per year), sell for less than the average (up to -24%) and have invested relatively little (€35,000 on average). Nevertheless, five farms alone account for more than half of the inertia of the first dimension, which severely limits the generalisation of the interpretations that can be made.

Axis 1 is positively correlated with costs per m² (Table 3). Intensifying the use of surface area is in fact accompanied by an increase in production costs (plants and seeds, fertilisers, crop protection, irrigation, etc.). There is also a positive correlation with annual payments, as the investments needed to increase the area under cover are often financed by borrowing. There is also a positive correlation with turnover per square metre, as increasing the area under cover improves productivity. Finally, we noted a negative but weak correlation with income (-0.34), leading us to put forward the hypothesis that farms positively correlated with axis 1 would see their costs increase more than their turnover, penalising income, in addition to the burden of debt.

Table 3: Results of the AFDM to identify factors or combinations of factors linked to viability

VARIABLES		DIMENSION								
		CONTACT			CONTRIBUTION			COS2		
		1	2	3	1	2	3	1	2	3
Modalities of qualitative active variables	*temporalité_investissements_1*	-0,35	-0,23	0,87	0,49	0,46	**9,35**	0,03	0,01	0,22
	temporalité_investissements_2	0,80	-0,69	-0,51	4,94	**8,04**	6,03	0,37	0,27	0,15
	temporalité_investissements_3	-0,88	1,16	0,07	4,15	**15,70**	0,08	0,26	0,45	0,00
	practice_group_1	1,17	0,47	-0,31	7,35	2,64	1,60	0,46	0,08	0,03
	practice_group_2	-0,76	0,24	0,00	5,49	1,17	0,00	0,52	0,05	0,00
	practice_group_3	0,40	-2,14	0,73	0,36	**22,43**	3,66	0,02	0,58	0,07
Active variables quantitative	*share of surface area under cover*	0,73	0,22	0,20	**22,22**	2,98	2,74	0,54	0,05	0,04
	area utilisation coefficient	0,58	0,37	-0,44	**13,84**	**8,27**	**13,87**	0,33	0,14	0,19
	hourly volume / 1000 m² developed	0,31	0,29	0,58	4,04	5,19	**23,85**	0,10	0,08	0,33
	proportion of time devoted to marketing	0,01	0,14	0,72	0,00	1,17	**37,04**	0,00	0,02	0,51
	share of turnover on the main circuit type	-0,35	0,71	-0,10	5,11	**31,05**	0,77	0,12	0,51	0,01
	average price differential	0,72	0,12	0,03	**21,55**	0,90	0,08	0,52	0,01	0,00
	investment (excluding land, market gardening only)	0,50	-0,01	0,11	**10,46**	0,01	0,94	0,25	0,00	0,01
Illustrative variables	*hourly income*	-0,34	0,33	-0,05	Illustrative variables do not contribute to the construction of dimensions			0,12	0,11	0,00
	annual income per market gardener	-0,30	0,40	-0,04				0,09	0,16	0,00
	EBITDA per market gardener	-0,08	0,35	0,01				0,01	0,13	0,00
	Turnover/sq.m	0,41	0,47	0,19				0,17	0,22	0,03
	costs/m².	0,69	0,17	0,36				0,47	0,03	0,13
	loan repayments	0,53	-0,18	0,20				0,28	0,03	0,04
	satisfaction_quality of life	0,14	0,29	0,05				0,02	0,08	0,00
	satisfaction_consistency_values	0,32	0,09	0,10				0,10	0,01	0,01
	overall hardship	-0,12	0,00	0,07				0,01	0,00	0,01

3.3.2 Dimension 2: towards optimising sales and investments?

The second axis accounts for 14.9% of total inertia. It is positively correlated with the concentration of turnover on one type of marketing channel and with a progressive investment timeframe. It is negatively correlated with practice group 3 (Table 3). It contrasts (i) farms whose turnover is relatively concentrated on one type of sales channel (from 84% to 100%) and which have invested progressively (7 farms out of 8), with (ii) farms adopting so-called classic (4 farms out of 6) or biointensive practices, where turnover is dispersed between several types of channel (at most 56% of turnover on the main channel) and whose investment strategy is described as intermediate (large initial investments which do not exclude later investments). In the same way as for axis 1, here six farms contribute more than half of the inertia of the second dimension. This justifies a cautious interpretation, especially as the sample size is small.

The strongest correlation with our illustrative variables, although still low (0.47), is with **turnover/m²** (Table 3). The **income indicators** have positive correlation coefficients with this axis, but they remain of the same order as for the first axis (between 0.33 and 0.4). In fact, all the farms with more than €20,000/year/market garden have more than 80% of their turnover concentrated on one type of marketing channel, although the reverse is not true.

3.3.3 Dimension 3: towards an intensification of work

The third axis accounts for 12.6% of total inertia. It is positively correlated with the proportion of working time devoted to marketing, and with labour intensity (Table 3). It contrasts (i) farms where the market gardeners allocate a relatively large proportion of their time to marketing (from 26% to 45%), and have a medium to high labour intensity (from 330 to 680 h / 1000 m² developed), with (ii) farms where the labour intensity is low to medium (from 120 to 370 h / 1000 m² developed) and where the proportion of time dedicated to marketing is between 10% and 15%.

Only three farms contribute just over half of the axis inertia. Here too, our interpretations must remain cautious, and any generalisation to all farms should be avoided.

The correlation coefficients of the axes with the illustrative variables are reduced as we progress along the dimensions. Although they are not very significant and cannot be generalised, they tend to highlight the **multidimensional nature of income**, which is constructed under the influence of numerous technical and economic indicators.

3.3.4 General comments on the results

Overall, the dimensions obtained are not very synthetic, in the sense that they are constructed on a **very limited number of farms** (between 20% and 40% of farms depending on the dimension), and that **the variables that construct them are not sufficient to explain the differences between farms** (the median of the $\cos^2$ of farms that contribute significantly to each axis is 0.4 for the first dimension, and decreases as we progress through the dimensions, reaching 0.27 for dimension 4, see table 3).

For example, there are oppositions between small groups of farms concerning the intensification of surface areas and selling prices, the diversification of outlets and the investment timeframe, and the intensification of work. But these oppositions are far from being generalisable to the whole panel, as some farms do not find themselves in these oppositions. **The relatively low correlations of the dimensions with our variables illustrating viability and sustainability do not allow us to suggest that the combinations of factors identified through factor analysis are resolutely favourable or unfavourable to viability** (Rivière, 2023). These results suggest that the conditions for success in micro-farming are not purely technical and economic.

4. Discussion

4.1 Limitations inherent in the sample and surveys

Although the MMBio project, by virtue of its ambition and scope, has made it possible to collect precise data on a large number of farms, **the number is still too small** for any statistical result to be considered sufficiently robust to draw generalisable conclusions. Furthermore, the way in which the farms were selected means that **the sample cannot be considered representative**. Above all, the panel is made up exclusively of farms that were in operation at the time of the surveys, i.e. that managed to stay in business between the time they were set up and the time of the survey, resulting in a survivor bias. By definition, **no farms that had ceased activity were included**, although analysing the data from these farms would probably be very enlightening in identifying the causes of failure in organic market gardening microfarms. In addition, the data and the results of the analyses based on it deal only with market gardening, one of the aims of the project being to produce technical and economic benchmarks relating to this activity, whereas 60% of the 42 farms in the panel have established at least one other production workshop on their farm.

The diversification of activities in these models is a central point. This can enable synergies to be developed between different workshops (exchange of organic matter, for example) or balance the economic results (Barbieri and Mahoney, 2009) and bring resilience to the farm. However, significant diversification of activities can also lead to less time being available for market gardening, or even a loss of efficiency, leading to poorer economic results.

It should also be noted that 40 of the 42 farms had been in operation for less than 12 years at the time of the first survey, and that **half of the panel had been in operation for six years or less**. In fact, most of the market garden micro-farms are relatively new and may not yet have stabilised their activity in technical, organisational and economic terms. As we have seen, the contribution of annual instalments to income can be significant, and the balance of short-term loans used to finance production tools during the set-up phase can have a significant impact on income (Rivière, 2023).

Finally, it should be remembered that the years studied are special. Among other things, 32 of the 38 farms with available accounts were surveyed in 2020, the year in which the **Covid-19 health crisis** began. The crisis had a profound effect on household consumption habits during this period, with the development of direct sales of organic vegetables (Renault et al., 2022). The post-crisis period also has its peculiarities, as **organic growth has not continued** as well as the Agence Bio predicted in June 2020 (Agra Presse, 2020). The years studied are therefore special from the point of view of the organic vegetable market, and stand out from the growth dynamic observed up until then. We have not quantified the impact of this 'year' effect (Rivière, 2023).

4.2 A restricted analytical framework and a limited method for dealing with a complex object with countless combinations

The work of the MMBio project identified the variability within the sample on multiple indicators, making it difficult to establish a typology of these microfarms, since there are many possible strategic and technico-economic combinations (Joyeux, 2017). This observation is confirmed by the AFDM conducted here, which indicates that **the data are poorly structured and that the successive dimensions are not very synthetic**. This is reflected by a steady decrease in the variance explained after dimension 1 and by the fact that one farm in three does not contribute to any of the first three dimensions. It was therefore necessary to restrict the number of variables in the analysis. It was by comparing the intermediate results of the MMBio project with the expertise of support and training professionals and, of course, installed market gardeners that the hypotheses and associated variables were chosen (Rivière, 2023).

The survey dataset thus offers the potential to explore other hypotheses, especially if it were enriched with data from other market garden microfarms to increase the panel (Rivière, 2023). In fact, other factors, technical and economic or otherwise, could be linked to viability: geographical isolation (from urban centres or catchment areas), socio-economic isolation (commercial outlets, technical or administrative support networks, suppliers, etc.); soil and microclimate context; start-up and investment aid; types of labour; technical expertise (practices, rotations, fertilisation, irrigation, etc.) and organisational expertise (planning, work organisation), etc. These hypotheses open up prospects for research into the viability of microfarms. These hypotheses open up prospects for research and development into the viability of market garden micro-farms.

4.3 Mixed results

4.3.1 *Adapting farming practices to the local context and the market gardener*

The classification of farms according to the practices they implement (fertilisation, pest management, intensification and tillage) refers, to a certain extent, to the three small-scale market gardening systems that Kevin Morel uses in his modelling work: manual microagriculture, biointensive market gardening and 'classic' diversified organic market gardening (Morel, 2016).

But these three categories are simplistic compared with the diversity of practices actually implemented by market gardeners, who have to adapt to the specificities of their biophysical and socio-economic context. **The three groups of practices were set up to assess a possible effect on viability, and not to produce prescriptive labels.**

Indeed, on closer examination, the heterogeneity of the combinations of practices within each group also reflects the **hybridisation of these sources of inspiration**, where technical choices are made according to the experiences and contexts of each individual (Morel, 2016).

Nevertheless, it seems that the most common practices are those related to the **biointensive model, which** bears witness to the influence of Jean-Martin Fortier (Fortier, 2012) on the many entrepreneurs who have set up market gardening microfarms over the last fifteen years.

4.3.2 *The mirage of a winning combination of factors*

Overall, **the multivariate correlations are stronger with the variables that contribute to income** (sales, expenses, annual payments) **than with income itself**. This means that any decision-making process leading to action on one element of the system (increasing the proportion of land under cover) in order to improve viability by acting on its correlated variable (turnover) must incorporate the effects on the other variables contributing to the construction of income (costs and annual payments). In other words, there is no linear relationship between a variable and viability, and the effects of changing one element of the system may be multiple and not lead to the expected improvement in income.

Hourly income has correlation coefficients in absolute terms of between 0.10 and 0.34 with the first five dimensions, i.e. low coefficients but which highlight the **multidimensional nature of income**, subject to the influence of several of the variables included in the analysis. The diversity of market garden micro-farms makes it difficult to identify generic conditions for economic success, as each situation is so specific (Rivière, 2023).

4.4 Viability, a broader concept than disposable income

It seems that the technical-economic approach is not enough to identify the conditions for success in diversified organic market gardening on a small area. Other factors relating to the area, work efficiency or psychological dispositions may also explain the different income levels for the same technical and economic situation. A dynamic perspective in the analysis, with more detailed consideration of post-settlement trajectories, could also shed new light on our problem. Questions of viability and sustainability can be considered differently in the short and long term, and some situations that are bearable in the short term may prove untenable in the long term.

The lack of correlation identified, for some farms, between income and satisfaction with that income, reminds us that there is no standard scale of viability to which all market gardeners can relate. On the contrary, viability is assessed according to the values and needs of the farmer and his family, with a close interweaving of professional and life projects. **Farmers and their families may have objectives other than maximising their income**: improving their quality of life, striving for autonomy, finding meaning in their activity, making a social and environmental commitment, having an acceptable workload, etc. (Morel & Léger, 2016).

One of the initial assumptions of the MMBio project was not to include the environmental dimension of sustainability, because the issues considered when the project was being set up were elsewhere: an upsurge in projects, reports of failures and abandonments due to lack of profitability, and a lack of perspective and technical and economic benchmarks for those providing support. However, the environmental dimension of the sustainability of this model cannot be overlooked, especially as it is often one of the motivations of those setting up this type of project. In his thesis, Antonin Pepin uses life cycle analysis to propose a **comparative study of the environmental performance of three market garden systems**: diversified micro-farming, specialised production under cover/greenhouses and open-field production (Pepin, 2022). The order of importance of the environmental impacts of these three highly contrasting systems can be completely reversed, depending on whether we consider energy consumption, impacts on the climate or on biodiversity, and whether we relate these effects per unit of surface area, per kg produced or per € of turnover. However, the micro-farm is judged to be a good compromise, with better yields than exclusively open-field production, less impact on the climate than specialised production under cover, and the promotion of biodiversity on the farm with a higher proportion of semi-natural habitats. The gradient of possibilities observed within MMBio farms suggests a potential gradient of environmental externalities (Rivière, 2023).

4.5 Ownership and prospects

The MMBio project is making a number of deliverables[6] available to different types of stakeholder (project leaders, market gardeners, advisers, trainers, local authorities or land lessors), such as summaries of the knowledge produced (technical and economic benchmarks, trials of practices, farmer innovations, success and risk factors), practical workbooks aimed at different target groups, and videos presenting the results of the project or related work.

The many discussions surrounding the project have led to the identification of a wide range of prospects for R&D (Rivière, 2023): continuing the analysis of the sample of MMBio farms (on aspects of mechanisation, marketing, through an individual approach to certain farms, or a comparison of production systems); broadening the system approach beyond the market gardening workshop alone, or even to the territorial scale, or by integrating the environmental dimension of sustainability; assessing the effects of climate change on work and exploring ways of incorporating this issue from the design phase; adopting a dynamic approach to the trajectories of market gardeners (investments, transfer); exploring the learning and knowledge of project leaders and market gardeners; networking the players to facilitate the collection, exchange and sharing of information and the co-production of knowledge; etc.

5. Conclusion

Axis 1 of the MMBio project has shown, on the one hand, the heterogeneity of income levels generated by small-scale organic market gardening and, on the other, that the economic viability of such an activity is indeed possible, even if the variability of income raises questions about the conditions required to achieve it. Although the research did not identify any technical or economic success factors, it does suggest that it is not so much the quantity of production factors (labour and capital) that leads to viability, but rather their nature (adaptation of equipment to use, to the user, to the range produced and to the soil and climate context, technicality or labour efficiency, for example). On the other hand, it is essential to take into account sustainability indicators in order to assess the 'success' of these projects. Income alone does not qualify as a measure of success, as improving income is often just one of a number of objectives guiding market gardeners' strategic choices. The knowledge produced by MMBio, including that from Axis 2 (experimentation with on-station practices: fertilisation, planting density and crop associations), has been combined with the expertise of numerous partners to produce operational deliverables for the stakeholders concerned. The aim of these deliverables is to provide the various players involved (project leaders, market gardeners, trainers, advisers, local authorities) with objective information to support the process of setting up small-scale organic market gardening.

Ethics

The authors declare that the experiments were carried out in compliance with the applicable national regulations.

Declaration on the availability of data and models

The data supporting the results presented in this article are available on request from the author of the article.

Declaration on Generative Artificial Intelligence and Artificial Intelligence Assisted Technologies in the Drafting Process.

The authors used artificial intelligence in the translation process from French to English

[6] https://wiki.itab-lab.fr/espacemaraichage/?MicromaraichageResultats

Authors' contributions

Supervision: Natacha Sautereau piloted the project to produce technical and economic benchmarks, and is responsible for the integrity of the data and the accuracy of the analysis.
Co-design of the interview guide for obtaining data: Natacha Sautereau, Kevin Morel, Dominique Berry, Cédric Hervouet, Nicolas Herbeth, Alexia Arnaud-Dupont, Anne-Claire Delestre, Mathieu Conseil, and all the project partners.
Data acquisition: All project partners
Statistical analysis of data: Simon Rivière, Alice de Lapparent
Interpretation of results: Simon-Rivière, Mathieu Conseil, Kevin Morel, Dominique Berry, Cédric Hervouet, Nicolas Herbeth, Natacha Sautereau, and discussions with groups of market gardeners and advisers.
Primary copywriting: Simon Rivière
Proofreading of the article: all co-authors
Obtaining financing: Mathieu Conseil

Declaration of interest

The authors declare that they do not work for, advise, own shares in, or receive funds from any organisation that could benefit from this article, and declare no affiliation other than those listed at the beginning of the article.

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