Case Study
Permacultural Organic Market Gardening and Economic Performance

Final Report

November 30, 2015

Summary

Since 2007, the Bec Hellouin Organic Farm has been developing an original model of market gardening combining a spatial organization inspired from permaculture and biointensive gardening techniques (E. Coleman, J. Jeavons, etc.). Using little mechanization, on a very small cultivated surface area, positioned on local markets, this model arouses very strong interest.

But is it economically viable? That is the question that the study led by the farm, the Sylva Institute and the unit of research SADAPT (Sciences Action Development – Activities Products Territories) INRA-AgroParisTech (National Institute for Agricultural Research)intended to answer. The special feature of this study is that it needs to be conducted on a farm where the techniques, the tools and new marketing methods are continuously tested, far from "traditional agricultural routine operations" that usually serve of support to the production of technico-economic references normally cited.

From December 2011 to March 2015, the market gardeners have systematically recorded their performances (nature of these, working time, inputs, etc.) and quantified the harvests grown on a cultivated surface area of 1,000 m^2, excluding walkways and surrounding areas, of which 42% are in greenhouses. Note that the 1,000 m^2 studied correspond to the most intensive area of Bec Hellouin Farm and should in no way be considered as sufficient to establish a micro-farm. Indeed, in permaculture, the very well-kept area is a part of the whole which includes the less intensive areas (to develop crops with longer cycles like winter crops), natural areas and buildings necessary for the proper ecological and commercial operation of the whole.

The modeling work based from the data collected shows that the cultivated area can generate gross sales (GS) sufficient to remunerate a person who has an agricultural status. The result, however, depends on the level of production per unit area. In 2013, the first year completely covered by the study, the GS was 33,000 € for 1,000 m^2. The following year, it reached 57,000 €. This increase is explained by various factors: increase of market gardeners' skills, adoption of innovative tools, reconfiguration of beds for better ergonomics, market diversification capable of producing shorter cycle vegetables and thus increase the number of successive crops during the year and installation of hotbeds to increase the period of production. The increase of the productivity required a higher work investment (a total of 3,026 working hours in the year of 2014 against 2,006 hours in 2013), attributable for the most part to the installation of hotbeds, which was not repeated to the same extent in 2015.

Based on an annual average weekly working time of 43 hours, agreed by the gardeners, the corresponding income for these two years was calculated under two hypotheses of amortizations and financial charges, high hypothesis (5,700 €) and low hypothesis (1,900 €). In 2013, the net monthly income was only 898 € under the high hypothesis (due to the purchase of new equipment). It reached 1,132 € under the low hypothesis (used equipment). In 2014, it is respectively 1,337 € and 1,571 €. These figures take into account the remuneration of an employee paid part-time at minimum wage, whose recruitment is essential to cover the amount of work required. The income would be significantly higher if the work is provided by a partner having an agricultural status.

This income approach shows the importance of the proficiency of the investments. There is a direct link between the level of intensification and the income, provided that the labor is proficient in order to prevent an insurmountable workload. A proficiency that refers to the market gardeners' skills, acquired through experience, continuing education, strategic skills (investment choices as well as market and social inclusion in the territory, etc.) and systemic skills (ability to observe the farm site in a global way in order to understand its strengths and weaknesses).

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Permacultural Organic Market Gardening and Economic Performance

Final report of the study

Sacha Guégan (Sylva Institute) & François Léger (AgroParisTech – UMR SADAPT)

Foreword

*The study "*Permacultural Organic Market Gardening and Economic Performance*", conducted since late 2011 by the Bec Hellouin Farm, the Sylva Institute and the UMR SADAPT (INRA-AgroParisTech) is now complete. Its purpose was to study a form of gardening in a small area, based on manual labor, very diverse and oriented towards local markets. Two intermediate reports have already been published in July 2013 and December 2014 and are available on the website of the Bec Hellouin Farm[1].*

The results presented in these reports have generated much debate, sometimes based on inaccuracies or misunderstandings. One objective of this final document is to clarify some of them, trying to always stay close to the data that has been collected and analyzed. The reading of the previous reports, however, should not be considered as superfluous: it will highlight the process and its evolution over time and the gradual emergence of certain concepts.

This report focuses on the global technico-economic results and does not include the analytical approaches that would go further to the understanding of the construction of the productive efficiency of the farm: the effect of companion planting and their rhythms, dynamics of soil fertility and biodiversity, among others.

These key questions could not be resolved from the data gathered over a period of three and a half years. Therefore, we expect to continue and expand the study to understand the underlying mechanisms of the economic and social viability of a permacultural micro-farm, in particular, those concerning the ecological functioning of the farm. Therefore, this report will not be the final outcome of the joint effort between the Bec Hellouin Organic Farm and the research unit SADAP.

1 www.fermedubec.com/publications.aspx

The genesis of a Collaborative Research Project

When Charles et Perrine Hervé-Gruyer settled down in Bec Hellouin, France in 2004, they intended to create a place for them to live, at the heart of an natural environment still largely preserved, where they could have access to a form of food sovereignty by growing healthy fruits and vegetables with their manual labor, respecting the environment and their convictions as much as possible. The discovery of permaculture offered them the holistic framework to conceive and build the project. Their curiosity led them to explore other sources of inspiration, experimenting with different methods of biointensive gardening from the North American pioneers, Eliot Coleman, and John Jeavons. Their personal experience confirmed the belief that organic agriculture can, and should, over the medium term, feed humanity. They wanted to contribute by providing evidence and demonstrating that it is possible to build a different future for our planet, once each one of us takes into account the repercussions of our choices worldwide. The link between the local and global urged them to wonder: *"How can we reduce our ecological footprint? How can we align our lives in coherence with our aspirations?"*

From that approach arose their decision, in 2006, of becoming professional farmers and to create a place which at the same time will be a space for organic food production, exchange of knowledge and skills, a place to share experiences and education. A place that could serve as a reference point and inspiration to people that share the same convictions, life project and methods of production. The transition to a professional scale made them discover the obstacles to implementing these projects in a very diverse system on a small area, mainly oriented to local markets, where the work would be based on manual labor and whose organizers are untrained and without agricultural experience. The absence of thechnico-economic references on which they could rely is flagrant: How, under these conditions, can a project be set up and argued before the agricultural and local authorities and the banks.

In 2010, the results were there: The harvests were abundant; the market gardening activity seemed rentable. Perrine and Charles became convinced that a very small farm will enable a decent living without being overwhelmed by work. Their multiplication will create jobs and would contribute to a healthy diet with a positive environmental impact. It became their ambition to demonstrate the effectiveness of the application of permaculture and biointensive organic gardening principles and to contribute to the production of references necessaries in order to the spread this model.

That is when their path crossed with François Léger, a teacher, and researcher at AgroParisTech, a member of the Urban Agriculture team of the Joint Research Unit SADAPT[2]. With a longstanding interest in "alternative" agriculture, he perceived an interest to document and to rigorously analyze the practices and the results of the Bec Hellouin Farm. This type of system developed on a very small surface, in fact, corresponds to numerous settling projects whose owners have not inherited the land. It is particularly attractive at a time when many public, private and associative actors are questioning agricultural development in urban and suburban areas, where neighborhood constraints

[2] UMR 1048 SADAPT "Sciences for Action and Development – Activities, Products, Territories", INRA-AgroParisTech.

and the characteristics of the real estate are increasingly contradictory with the "modern" forms of agriculture. His research concerns met with the willingness of Perrine and Charles to provide the elements to those interested in to setting up a project.

It is from this encounter that the collaborative research work was born and whose results are presented in this document. The major conclusion confirms the initial empirical intuition of Charles and Perrine: ***it is possible to produce a significant yield on a small area cultivated mostly manually, and to generate enough profit to ensure an adequate income to someone with an agricultural status.***

This statement is original in many ways. However, it needs to be discussed to fully understand the scope and the limits. Prior to this, we are going to come back to the main choices that preceded the establishment of Bec Hellouin Farm (permaculture and the techniques of biointensive organic micro- farming) before presenting the methodology of the study and its main results.

The "Method of the Bec Hellouin Farm''

What defines the method developed and applied at Bec Hellouin organic farm, it is a combination of coherent principles mutually reinforced, whose sources of inspiration are situated in two complementary directions, permaculture (Mollison, Holmgren, etc.) and biointensive organic micro-farming (John Jeavons, Eliot Coleman). These references are presented in their website under "*fond documentaire".*

Permaculture

This pragmatic approach, inspired by the ecological science, was proposed by the Australians Mollison and Holmgren[3] in the 1970's. It is conceived to enable the individuals and communities to rethink the relationship between societies and their environments, endangered by a concept of development based on mining the natural resources (fossil fuels, minerals, water, biodiversity, etc.). In a very simplified way, we could say that the objective of permaculture is to create "real life ecosystems ", based on the interactions of their various components to optimize its autonomy and ensure the quality of life of the people who are concerned. The design, construction, and management of this "permacultural ecosystem" are the result of a global vision of the site, its functioning, and its dynamics, in accordance with the social, ecological and economic aspirations of those who live there. The permaculture design is always contingent on the places and people. To read about Charles and Perrine Hervé-Gruyer presentation of the Bec Hellouin Farm, go to (http://www.fermedubec.com/permaculture.aspx).

The general organization of the Bec Hellouin Farm (see Figure 1) is the fruit of this "reading of the permaculture" applied to this particular site. The farm is organized into different areas, corresponding to the characteristic "Zones" of permaculture design.

[3] Mollison, B., Holmgren, D (1981). *Permaculture One: A Perennial Agriculture for Human Settlements*, 1ST edition. Ed. International Tree Crop Institute, Australia.

Figure 1: The Bec Hellouin Farm, drawn by Charles Hervé-Gruyer
The site is crossed by the Bec River, flowing from the South-West to the North-East. The cultivated area is located towards the left river bank and the buildings towards the right river bank.

The market garden itself is structured as follows:

- **Zone 0:** Greenhouse workshop, located in the heart of the cultivated area where the tools and equipment are stored, also where work meetings are held and where the vegetables are prepared (white circle in Figure 1).
- **Zone 1**: the greenhouses, the “Pommiers”, "Rivière" and “Ile” areas, close to the workshop are particularly taken care of, to optimize their productivity (circled in yellow in Figure 1). The island “Ile” is surrounded by ponds dug during the implantation of the gardens, which help to moderate the microclimate (protects against freezing, etc.), to produce biomass (reeds, sludge) recyclable on the raised beds, and to house a useful biodiversity (frogs, etc.).
- **Zone 2**: The mandala, the agroforestry land southwest of the greenhouses, helps protect from the prevailing winds and is subject to a lesser intensification. It is dedicated to the less demanding crops (perennial, squash, etc.) that complement the production of the Zone 1 (in orange).
- **Zone 3**: the forest garden to the west, the agroforestry belts to the southeast of the greenhouse and the mandala are involved in the moderation of the local climate. Subject to little care, they produce mostly fruits that complement the vegetable supply of the farm (in green).

- **Zone 4**: mainly composed of uncultivated areas essentially devoted to animals, with an amount of biomass that can be distributed to the cultivated areas the (the remaining, not circled in Figure 1)
- **Zone 5**: consisting of meadows and surrounding woods that contribute to the functioning of the local ecosystem (climate and habitat of auxiliary species..) but also the nearby territory where we can find free resources like manure, ferns, green waste that the farm contributes to recycling.

The biointensive organic micro-farming

This term refers to a set of methods aimed at maximizing organic vegetable production on very small areas which have little or no mechanization. They are part of a critical reading of industrial agriculture and food systems and their ecological, social and cultural impacts. Together with permaculture they share the same ambition of autonomy and endogenous development of local communities, supported by a "holistic ecological intelligence". The experiences of John Jeavons and Eliot Coleman, which gave rise to numerous books, are the most used sources of inspiration at the Bec Hellouin Farm. One of their common principles is to privilege manual labor to optimize the densities of sowing or planting, and thus the production by unit area. Two complementary routes conducted by the Bec Hellouin Farm to further strengthen the principle of intensification: intercropping, to better explore verticality and to optimize the capture of solar energy as much as the exploration of different soil horizons; relay cropping, where a new crop is installed before the end harvest of the previous crop. The three principal "methods" of cultivation on the farm represent three different ways of implementing this ambition of intensification:

- **Permanent mounded raised beds:** increase the cultivated area and the structure of vegetation "floors", thus ensuring better capture of solar energy.
- **Permanent flat beds:** rather dedicated either to single seed sowing or high-density intercropping.
- **Hotbeds:** inspired by the practices of the peri-urban farmers of the nineteen century. They consist of fresh horse manure windrows that while composting, will generate heat (up to 70-80 ° Celsius at the core). The seeding boards are placed on the hot layer (the warm layer acts as an electric blanket without electricity consumption) that is 15-20 cm of soil to plant the crops. The heat production will help the early crops to launch earlier. Compost production is very useful in the context of the farm whose original soil is not very fertile. The hotbeds allow the closing of a cycle at the scale of the territory: this horse manure from village's equestrian club was previously a waste product, piled in a field as a potential source of pollution.

The hotbeds illustrate an essential pragmatic permaculture principle: seeking autonomy is not the purpose and should not be confused with a desire for self-sufficiency. The integration to the territory, the strengthening of the relationships with the members of the local community, the creation of social and ecological synergies with the neighbors (in our case the equestrian club) will allow a non-market access to nearby resources which is an integral part of permaculture design.

The soils and their management

Located in a valley occupied by hydromorphic natural grassland, the Bec Hellouin Farm was hardly, *a priori,* intended to be agricultural. The only advantage appeared to be the unlimited access to water. The soils, however, were not suitable for vegetable gardening: with almost a superficial peaty soil horizon of fifteen centimeters thick, mainly composed by silt and organic matter difficult to mineralize, on a soil horizon formed by marl-alluvial soil rich in flint. Building up the soil to make it more suitable for gardening was a key issue during the set up. Important amounts, mostly in the form of composted horse manure have therefore been incorporated into the gardens to establish the different cultivating beds and mounded raised beds, giving as a result a type of soil fairly similar to the “ancient” vegetable gardens, like the floating gardens in the Somme department “hortillonnages de la Somme” or the “green belt” gardens of Paris of the nineteenth century, but shallower (30 cm at the most for the flat beds). This "soil building" is perfectly consistent with the spirit of permaculture, which considers that to act on the initial conditions of the system "human-nature" is often a prerequisite “sine qua non” for engaging it in a way "of ecological aggradation" ensuring its durability and resilience.

Scope and purpose of the study

Working hypothesis

Thanks to its location and its soil, the Bec Hellouin Farm seems unique in the universe of market gardens. That uniqueness is reinforced by the extreme originality of its design and the techniques implemented. The farm as a whole combines training and food production, and definitely, could not be considered as "a reference that can be literally reproduced". The hypothesis formulated at first was more general: ***the implementation of permaculture principles and biointensive organic micro-farming allows producing a significant yield on a very small area, cultivated mostly manually, and generate enough profit to ensure an adequate income to someone with an agricultural status and satisfactory working conditions.***

This hypothesis refers to two dimensions and two supplementary questions:

- **The economic viability***: could a market gardening system such as that of Bec Hellouin generate a decent income and ensure over time?*
- **Liveability (quality of life):** *is the work needed to generate that income, bearable in quantitative (working time and its distribution over the year…) and qualitative terms (difficult work conditions and the possibility of taking days off…)?*

Market garden production, the main purpose of the study

In order for these responses to become a source of inspiration for the market gardeners and the project leaders, it was necessary to connect our results to the principles and practices demonstrated by the design and the management of the farm. However, the study of this singular farm, with its peculiar workforce structure, its specific combination of activities (market gardening, training center, guest house...), and trade channels (produce for sale at the farm, vegetable baskets, upscale restaurant, wholesalers...), would raise the following questions: will it produce enough lessons to be truly useful to others? What will be necessary to study from this farm in order to produce the results that can be detached from this singularity?

On the other hand, the working data collection needed to answer these questions could only be gathered by the market gardeners: it was impossible to imagine having a person in charge of following their daily activity. It was necessary to find a good balance between the quality and quantity of the information, in coherence with their availability.

We, therefore, decided to restrict the study to the production obtained on a coherent section of the farm, corresponding approximately to 1,000 m^2 of cultivated beds, excluding the walkways and surrounding areas.

From production to labor remuneration

It was not enough to know the production, it was also necessary to describe the means used to obtain such production: working time, materials and equipment, implemented practices, commercial, non-commercial inputs (plants, seeds, treatment products, soil amendments and fertilizers, etc.).

The hypothesis that we intended to test, was not limited only to the production but also to the issue of labor compensation. Therefore, it was necessary to find a solution to convert this type of production into an income that could manage the expenses (inputs, materials, and equipment).

The farm accounting provided the means required for calculating these expenses, and when there was no other solution, to allocate them entirely to the studied surface area (like some hardware investments such as tools). The calculation of the income, in turn, refers to the characteristics of the commercial channels of the farm; it soon became clear that these would have an impact on the production: lack of market opportunities, cultivation of specific products for certain customers, etc. We have developed a method for calculating the market value of the production for freeing us from these characteristics, but only in part. We will later see how the abstraction of the commercial reality of the farm puts into the debate the key questions for those who would want to be inspired by the results of this study.

A study conducted under real conditions, not an experiment

One of the important characteristics of this work, led over more than 3 years is that **it was carried out on a farm, under the real conditions of a market gardening business**, subject to customer, regulatory and priority management constraints, instead of being deliberately conducted in a testing center disconnected on purpose from the marketplace and the events that are part of the daily life of a market gardener. The goal was to observe and not to interfere with the decisions related to the production which belonged entirely to the farm team, and were taken without any external instruction. A farm constitutes a whole, the actions related to the production were obviously related to all the other aspects of the business (market opportunities, human resources…), and therefore, as consequence, the results observed in the framework of the study may have been impacted by factors not related directly to the analyzed field, precisely the production. These elements will be widely covered in the discussion.

The collection protocol and data processing

The studied plots

Their personal experience as market gardeners as well as their interest in books relating to the Parisian gardeners of the nineteenth century had brought Charles and Perrine to consider that a cultivated area of 1,000 m^2 managed in a very intensive way (high densities, intercropping, relay cropping…) could ensure enough income to a person with an agricultural status. It was this hypothesis that led to the dimensioning of the studied system, especially since this surface seemed compatible with the investment capacity of market gardeners who will have to recover the necessary information.

The selection of the plots included in the study was also dictated by the following hypothesis. Which implies to focus our attention on the areas cultivated in the most careful and most intensive way, that corresponds to the "Zone 1", which we have previously defined as the greenhouse, Pommiers, Rivière, and Ile area. However, the Ile area seemed very particular: at the center of the pond, the ecological conditions (microclimate, water supply, movement of insects, etc.) were more difficult to reproduce. The "Ile" was therefore excluded from the study. To complete the 1,000 m^2, it was therefore decided to add to the areas identified in Zone 1, a part of the Mandala, belonging to the "Zone 2", less intensively cultivated and subject to less maintenance.

Table1: main characteristics of the areas included in the study.

Area	Description	Cultivated area on 31 May 2013
Greenhouses	Undercover area Wooden bordered beds	421 m^2
Pommiers	Open field setting Wooden bordered beds Agroforestry area	116 m^2
Rivière	Open field setting Flat beds Agroforestry area	117 m^2
Mandala and Small Mandala	Open field setting Mounded raised beds Agroforestry area	378 m^2

Within the selected areas, the monitored areas, correspond exclusively to the cultivated beds (excluding walkways and other uncultivated areas), amounting 1,032 m^2, at the beginning of the study (December 2011), of which 50% of the vegetable cultivated areas are located in the valley. The Zone 1 represents 63% of the cultivated area and the

undercover area 42%. The latter proportion is close to the average observed on other organic micro-farms studied in the context of the thesis of Kevin Morel, a Ph.D. student at UMR SADAPT. The main characteristics of the different areas are shown in Table 1.

The different plots were included in the study since December 2011, as the previous crop cycles were completed. The targeted area was reached in April 2012. Once the "cruising speed" was reached, the studied cultivated area, still close to 1,000 m^2, had undergone some variations, inherent to the life of the farm: rearrangement of the plots, especially in the greenhouse and in the area Mandala; standardization of the bed lengths, in order to facilitate the management of the thermic films.

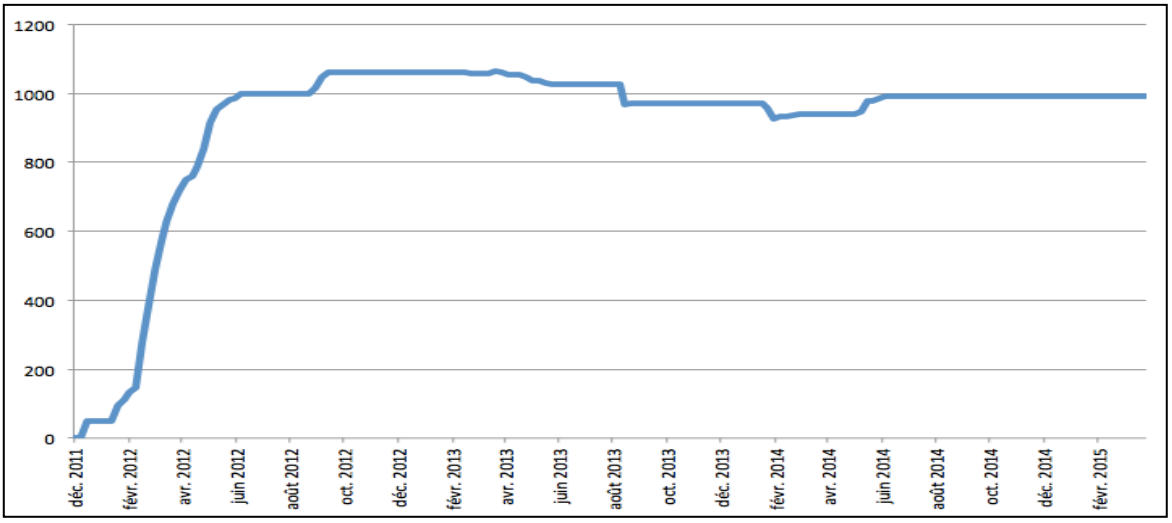


Figure 2: Cultivated surfaces taken into account in the study From December 2011 to February 2015

In order to allow relevant comparisons, the following results were brought to 1,000 m^2 by a simple rule of three. It is important to emphasize that the Bec Hellouin organic farm is not limited to these 1,000 m^2. These alone would not make much sense: the ecological interactions put at stake, the crops that they allow to grow, and supply, or not the customers, implies the existence of a wider environment, which can just as well be part of the farm or not. In either case, it is necessary to keep in mind that it is up to each project leader to build these interactions and the wider ecological and economic environment according to the local context.

Data collection

To describe the production and the factors allowing to obtain it (practices, labor, inputs, etc.), it was decided to measure the information on the scale of individual procedures on each cultivated bed. That is to say, that each time a person performed any work on the beds, she/he needed to record all the information regarding the procedure: working time, nature of the procedure, the means used (seedlings, plants, tools, products, etc.) and for the harvests, amounts and units (kg, bundles, item). These measures concerned only the productions of the monitored plots (vegetables, aromatic, edible flowers, etc.). In the

agroforestry land (Pommiers, Rivière); the fruit crops were not accounted for. The record sheet is shown in Figure 3.

DATE : .....

PERFORMED BY : .....

			minutes	minutes		minutes	minutes	nbr plants or grams	minutes	minutes	minutes	minutes	minutes		kg/b/u	if it is the end
			SET UP			PLANTING			MAINTENANCE				HARVEST			
Plot	Crop (type)	Variety	Mecanized	Non mecanized	Mulching (Org / Non Org)	Seeds	Transplan-ting	Quantity	Fertilization	Weeding	Watering	Other (indicate observ°)	Duration	Quantity	Units	END OF CROP

Personal observations:

Figure 3: Record sheet for the procedures on the studied beds

The data collected would then be transferred to Excel® spreadsheets; this task was entrusted to the engineer in charge of the study at the Sylva Institute, who was in charge of the quality control of the data (consistency of the information, etc.). The spreadsheets were structured like the collection sheet: each intervention is treated as an observation (row); the different variables listed in the table were registered directly in columns.

The additional details registered on the "observation" column, were not arranged as coded variables (for example, the nature of the fertilizers was registered, but these were not systematically coded per kind thus defining a new variable). This additional step has not been implemented in view of the significant time it would have required and the uncertainties associated with these comments. Some information regarding the cultivation process remains accessible exclusively on a qualitative fashion. This is the limit when it comes to answering some questions about the explanatory factors of production results, for example, fertilization. This information may, however, be taken back later in a second study.

Similarly, some important information could not be registered due to lack of reliable measurement means. This is particularly the case of irrigation, despite the importance of this factor in gardening. There are several watering techniques on the farm: drip irrigation, sprinklers and hand sprinklers and nozzles. But, because of the lack of reliable

measurement equipment used in these conditions (flow meters, etc.), it was not possible of quantifying it. The only known data, therefore, relates to the time that the gardeners spent on irrigation.

Working time

Recording of working hours

All the work performed on the studied plots was registered, regardless of the person who was performing the work. Therefore collected as follows:

- The procedures performed by the staff
- The procedures performed by the long-term trainees during their agricultural training (BPREA, agro-engineering, etc.)
- The procedures performed by the short term trainees at the School of permaculture of Bec Hellouin (gardening, farming, and permaculture training courses)
- The eventual procedures performed by others (for example: the kitchen chef harvesting his own products). In this case, the total time spent in the garden was written down by another staff member dedicated mainly to work in the cultivated areas and was recorded on the basis of the time spent and harvested products.

Working time calculation of the training course participants of the permaculture school

The farm staff and long term trainees (trainees in agricultural courses) completed their own work sheets each day.

The trainees attending a training course as part of the Permaculture School would perform more specific procedures, thus, it was not justified to teach them how to fill the recording sheet. In addition, a significant portion of time spent on the field was dedicated to lecture. Finally, most of these people were beginners in gardening – or complete novices- and, therefore, they were spending a lot more time accomplishing a task than a certified market gardener. The maximum had been done in order to ensure that these training courses would not take place in the studied plots. Sometimes this was not possible. The summer fruit vegetable course training had to be performed in a plot that was in the greenhouse; this was therefore included in the study. In this case, the instructor registered the corresponding time that the market gardener would normally spend for the same task which was performed by the students. The impact of this choice (did the teacher estimate correctly the time which would have dedicated the market gardener?) could be tested. Since the influence is very minimal, given the low number of cases of this type, it can be considered insignificant.

Work in the garden and other tasks

This recording method allows us to calculate the daily working time and the number of people involved in each portion of land. The work performed on the beds represents only a portion of the working time related to the market garden activities. There is a variety of tasks that also need to be included; the maintenance of walkways, surrounded areas like fruit trees, bushes, tools and equipment. In addition, all people working regularly on the farm dedicated a variable part of their time to other activities outside the gardens: maintenance of site and buildings, commercial and administrative duties etc.

These activities, unevenly distributed during the year, are essential to the smooth functioning of the production activity. However, they have not been accounted for in our study protocol, focused exclusively on the latter. In order to judge the "working time" dimension from the liveability (quality of life), it was, therefore, necessary to set ourselves a standard of work time acceptability dedicated to the monitored crops, leaving enough time to perform other tasks.

This additional workload is commonly estimated as a third of the total working time on an annual average. Referring to these figures, we set an arbitrary standard of 30-hour work week in the garden per full-time employee (FTE), for a total workload of 45 hours per week and an annual workload of between 2,100 and 2,200 hours, which appear to be acceptable under what is commonly established in the profession.

The prices

In order to overcome the agricultural framework and to begin an economic analysis, it was necessary to assign a value to the harvests, that is to say, to pass from *production* to *income* and to *gross sales GS.*

This calculation could be done a priori by the accounting of the farm but this task had quickly become difficult: an important part of the sales was carried out in the form of vegetable baskets, whose composition was variable and the price set on a consisted basis, regardless of content. To the extent that these vegetable baskets were not composed exclusively of products from the studied plots (we recall that the total cultivated area is superior to that of the study), it was almost impossible to assess the value of the production of these beds from the sales of the vegetable baskets. We had to overcome this constraint and more generally, freed ourselves from the commercial characteristics of the farm, by moving closer, as much as possible, to the most representative prices of the market, for the local organic vegetable sales. **The following price sources were therefore used to calculate the value of the vegetables produced on the studied beds:**

- **Market price list of the Regional Group of Biological Agriculters Upper Nor-Normandy (GRAB-HN)**, which we will call later in this document the "GRAB market price list". This is a survey for organic local market gardeners by the GRAB-HN from May to November, every month or every two months. First the GRAB send a list of vegetables (some aromatic, some fruit, etc.) to the market gardeners. Those who wished to participate would then send back the document with a list of the prices they charged locally (the farm participated systematically

to the survey). Finally, the GRAB returns back to the market gardeners the completed list with the minimal, maximal and average prices recorded (see Annex). For each vegetable listed in the market price list, the average price recorded locally in the region is available in May. The average price in the GRAB market price list will be called later in this document **GRAB price.**

- **The prices of vegetables sold every week at the farm, in the form of vegetable baskets or not, and which are not included in the GRAB list**. This configuration is for example in March-April, when the first early crops are harvested but the GRAB market price is not yet available (the first GRAB market price list is made in May). Alternatively: if the harvested crop does not appear in the GRAB market price list, but it is sold in the vegetable baskets (examples: garlic, scallions, oregano) the prices are set by the farm, consistently with what is happening in neighboring markets. **This price will be called "farm price" later in the document.**
- **Vegetable prices sold mainly to restaurants which are customers of the farm** (mostly gastronomic or starred restaurants), that don't figure in the GRAB market price list and are not sold (hardly ever) to "ordinary" farm customers. These prices are set every week and will be called **"restaurant price"** later in this document.

If a vegetable, whether sold, processed or consumed on the farm (in particular by the catering of the eco center) appears in the GRAB market price list, it is valued at the GRAB price. If it does not appear in the GRAB market price list, but it was sold in a vegetable basket, to the regular customers or wholesalers, it is valued at "farm price". If the harvested crop is sold only to restaurants (edible flowers, mini vegetables, etc.), is valued at "restaurant price".

To summarize, the selected price is the first available for the concerned product, taking the following order: "GRAB price", "farm price", "restaurant price".

Examples:

- In August, the price of tomatoes is shown on the GRAB-HN market price list (the other market gardeners that produce tomatoes indicated their selling prices on the GRAB-HN market price list). When the average local market price is available, it is used to value the tomatoes. There are two other prices that are also available (the ones used for the vegetable baskets and the restaurants) but these not taken into account: the priority is given to the GRAB-HN prices.
- During the same period, oregano is also sold. This product is not in the GRAB-HN market price list but is sold in the vegetable baskets. It is, therefore, the farm price that is taken into account. The price at which oregano is sold to restaurants is not taken into account.
- In March-April, the pink radish bundles are harvested. The first GRAB-HN market price list is carried out in May, thus, there is still no GRAB-HN prices for these radish bundles at this period. Since they are sold in the vegetable baskets, it is the farm price

that is used to value them. The price at which these radishes are sold to restaurants is not taken into account.

- Edible flowers are sold to restaurants. This type of product is not in the GRAB-HN market price list and is not marketed in the vegetable baskets. It is the restaurant price that is taken into account because it is the only one available.

The estimated production is that which is marketed

The farm marketing methods (AMAP Association for Maintaining the Peasant Agriculture, vegetable baskets, and restaurants) imply that the crops are made to order and include only vegetables whose qualities correspond to those commands. As a result, post-harvest losses (storage, unsold) are low; a portion of any surplus can be consumed directly on the farm, especially in the catering of the permaculture school.

However, this made to order “logic” can lead to significant losses "in the field". Some vegetables that could be perfectly marketable are not harvested at the right time due to lack of demand. In rare cases, they can be harvested and sold to wholesalers, but this is not possible and interesting, despite the potential discount in comparison with the GRAB or farm prices, even if the volume that could be marketed is enough, which is rarely the case given the extreme diversity of the crops and, the relatively limited area devoted to each. Therefore, a portion of the vegetables is sometimes left in place. They will be treated like weeds and will be later composted or used as mulch, at the time of the next crop preparation. These "unrequested" vegetables are not recorded in the harvests.

The production that we have evaluated is not the total production, but the production designated to meet the orders and thus commercialized as long as such requests were carried out.

At the end of 2012, this dependence on market opportunities resulted in the plots in this study not being cultivated because of the anticipation of a lack of commercial outlets. In a purely experimental perspective, it would have been useful to plant vegetables to best study the productive potential. On a farm subject to cost constraints, it was not possible to start crops which we knew would not be sold: It would represent more costs (plants, seeds, labor) without gross sales in exchange.

LESSONS FROM THE STUDY

The study performed at the Bec Hellouin organic farm had led to a key lesson: it is possible to produce a significant yield on a small area, cultivated mostly manually, and to generate enough profit to ensure an adequate income to someone with an agricultural status.

The harvests and their value

A steady increase during the study

The value of harvested vegetables increased steadily during the study. To better visualize this increase, we have chosen to show that production on rolling values per year. In Figure 4, below, the value for each month corresponds to the sum of the values of the previous twelve months. The starting point of these curves is, therefore, the month of May 2013, one year after the introduction of all the beds followed in the study.

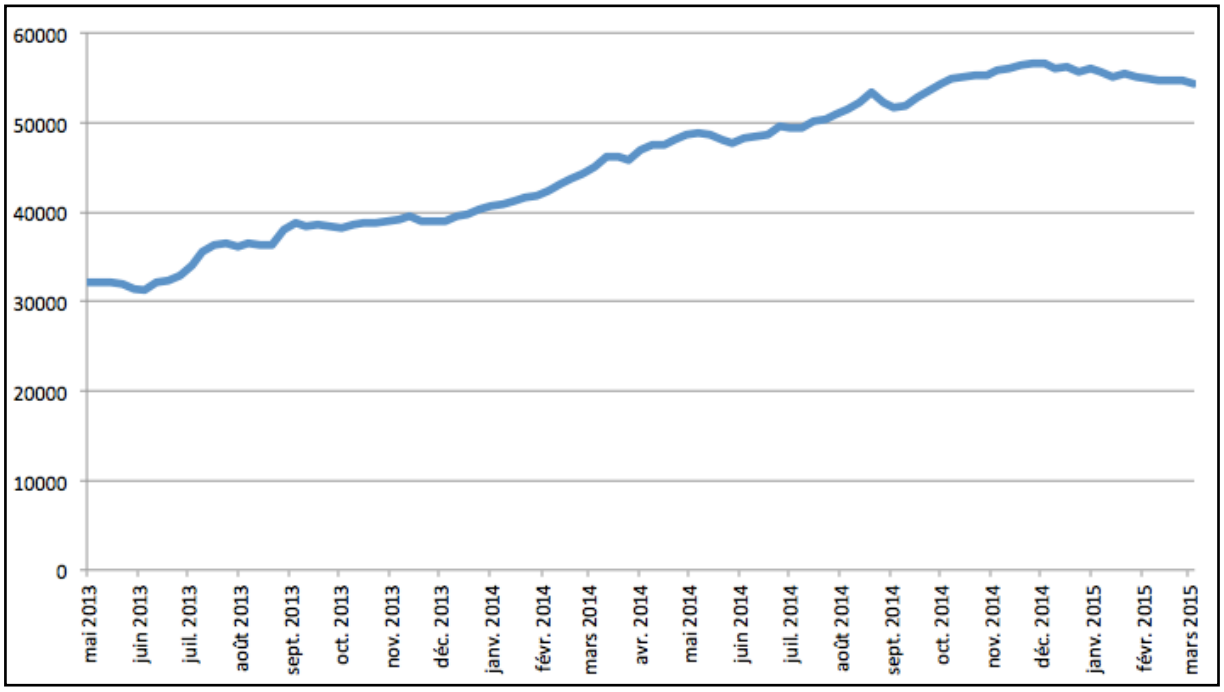


Figure 4: Rolling year values in euros of vegetables sold

The accumulated value over 12 rolling months passed from 32,400 € in the period from June 2012 to May 2013 to 54,600 € from April 2014 to March 2015, that being 69% compared to the first studied period. It reached a maximum of 57,300 € on the 2014 harvest, that being 76% compared to the first studied period.

The production is very seasonal

By expressing the values produced on a quarterly rolling basis, that is to say, by assigning to each date the calculated production value of the preceding three months to that date, we immediately notice the strong seasonality of the production, certainly related to low winter outputs (see Figure 5). This calculation allows us to see that the progress observed over the three years of the study takes place in each period: the monthly values of the third year are superior to those of the second year, which are themselves superior to that of the first year. We notice however that the progress concerns more particularly the spring and winter periods.

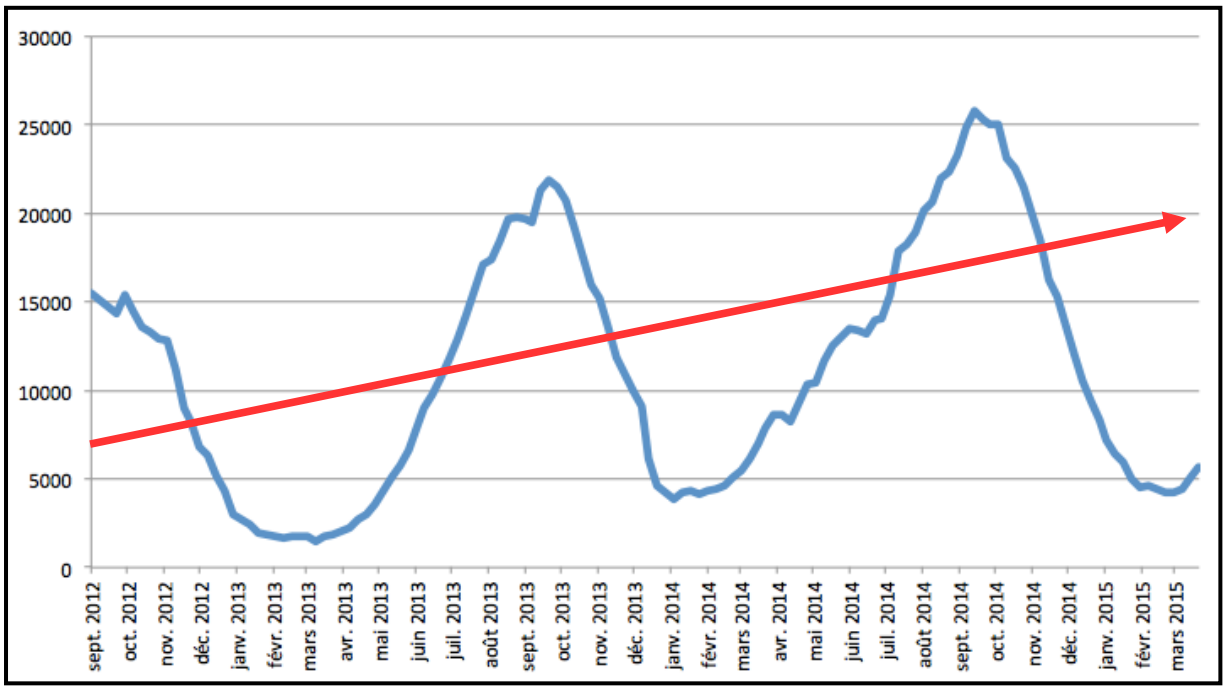


Figure 5: Quarterly rolling value in euro of the vegetable production.

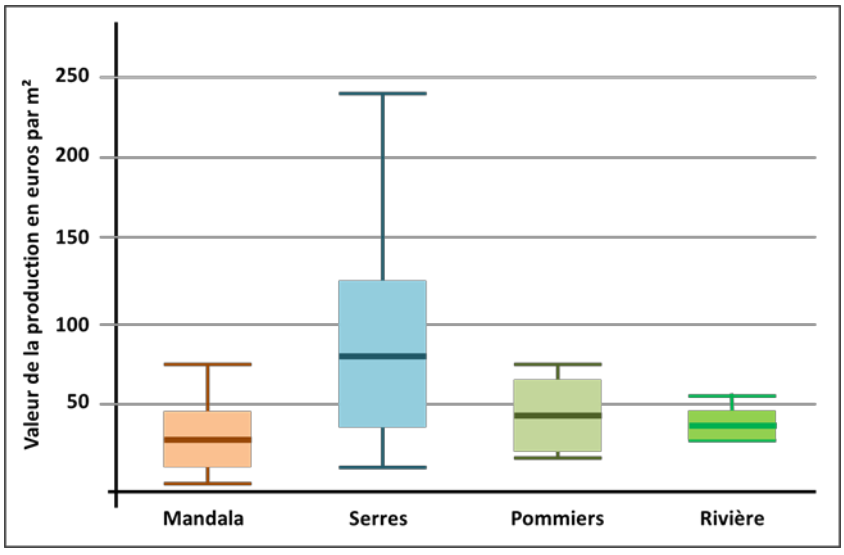
The productivity per unit area is varies widely across the different areas

The examination of the production shows a great variability between and within the different gardens. March 2014 to March 2015 (Figure 6) was the period where the intensification of cultivated areas was the highest. The average production is significantly higher in the greenhouses (80 € / m^2). This result is logical. The production period in effect is more extensive and there is a greater possibility for diverse crops. It is also in the greenhouse where we will find some of the most productive crops with higher added value (tomatoes, eggplants, etc.), that are difficult to cultivate in open field under the Normandy climate. However, we noticed that the productivity per m^2 of the different plots is also more variable. This is due to two factors. The first corresponds to the many intercropping: the results are significantly higher in the plots where many of the crops

succeeded each other or were associated with "higher crops" (tomatoes, eggplants, etc.) was higher (up to five crops). This is clearly the most important factor, as evidenced by the lower productivity in the small greenhouse where these associations were less systematic. The second corresponds to the installation of hotbeds in the greenhouse on a relatively small number of plots, which allowed furthering expanding the productive period increasing the soil fertility and yields. Furthermore, these two factors, when combined, on 6 of the 37 plots identified in greenhouses, explain the importance of the observed variability.

The lowest production was obtained in the Mandala (28 € / m^2) this result is also logical: this area in "Zone 2" is subject to less maintenance, the relay crops are cultivated less frequently due to the greater proportion of perennial crops (especially aromatic), and it receives crops with lower commercial value.

The results of the Pommiers and Rivière areas, located in "Zone 1" in open field, more maintained and intensified, are significantly higher (respectively 48 and 38 €/m^2) and their variability is more limited. The difference between the two areas is due above all to the crops grown, more or less profitable (e.g. the zucchini, very productive although cheap is exclusively grown in the apple orchards). If we relate these results to the hectare (480,000 and 380,000 euros) it would remain extremely decent compared to more traditional organic market systems. Nevertheless, it is difficult to give precise figures for this comparison, since the yields, in this case, are calculated on the entire surface area of the plots, walkways, and passageways and not only in the strictly cultivated areas.



<u>Figure 6</u> : Production value per m^2 (min / avg/max) in the different studied areas - Period from March 28, 2014 to March 27, 2015

The Comparison between the period from March 2014 to March 2015 and the period from May 2013 to May 2014 shows that the increase in production in all the studied areas (Figure 7) was uneven. It more than doubled at the Mandala (+210 %), for the

greenhouses and the “Rivière” areas the increase was roughly equivalent (176 % and 180 % respectively), and lower in the Pommiers area (128 %). The greater increase in the " Rivière " area is mainly because in 2013 -2014 face to the lack of market opportunities some plots remained longer without crops in the “Pommiers" area: the productive performance appears well linked to the rapid succession of crops on each field.

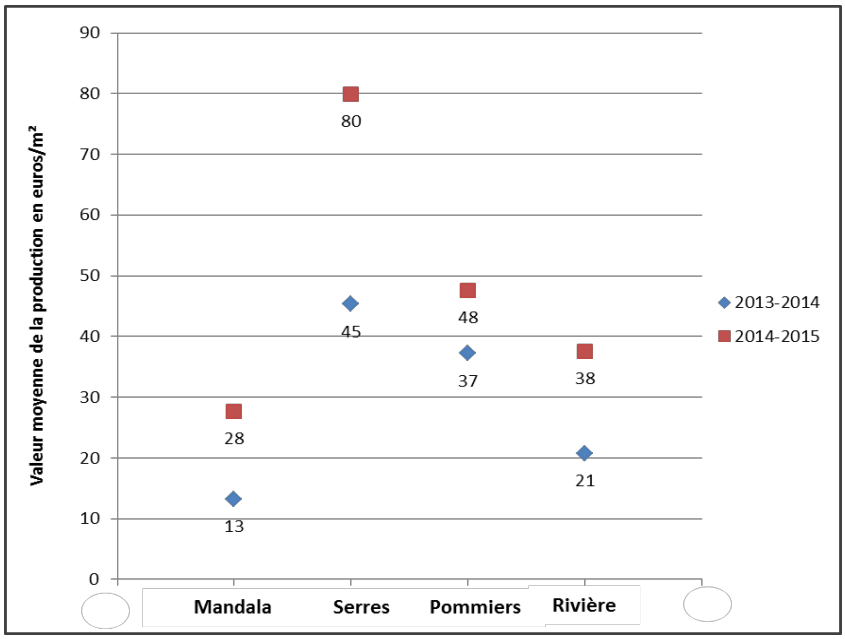


Figure 7: Evolution of the average value of the production in euros per m² between the period from May 2013 - May 2014 and March 2014 – March 2015.

The causes of the increase in production

An effect of the study itself

Various factors explain the progress of production during the study. The first is due to the effect of the study itself. We cannot indeed exclude that, because they were directly committed to the study, the market gardeners paid greater attention and maintained the plots more diligently. This was possible for the market gardeners but also for the trainees, because they were more motivated by participating in this study. One can also think that the very fact of taking note of their performance has helped them raise awareness of the problems they had not necessarily paid attention to so far and they corrected spontaneously. For example the reconfiguration of the Mandala which we will discuss later.

The study aiming at proving the effectiveness of the Bec Hellouin Farm system has also had a “self-fulfilling" effect that is very difficult to assess.

More generally, one can also assume that the market gardeners’ skills have increased during the study. Some of them, beginners, at first, have gained experience.

Finally, the recordings and direct observations allow us to assert that the crops were altogether better maintained at the end of the study than at the beginning of it. This was verified by the market gardeners and the trainees. However this is difficult to quantify because it is not reflected as working time data: the amount of time devoted to routine maintenance of the crops, especially weeding, increases significantly from one year to another, but the duration of each of these procedures tends to be reduced. Finally, the total workload dedicated to these tasks remains approximately constant. That brings us to consider that the key point lies in the regularity of the procedures. **A greater control of the market gardening activity allows us to act at the right time and avoid being overwhelmed**, which requires major intervention time.

Improvements of tools and equipment

At the same time that the study was taking place, the Bec Hellouin Farm continued its research on the tools; including the development of innovative ones (see the document on *Innovative tools research in favor of permaculture micro-farming*, available on the Bec Hellouin website). The improvement of existing tools and the implementation of new ones (*Campagnole, greens harvester etc*.) which are more ergonomic and efficient, have had a direct impact on the workload, its level of difficulty, and also the effectiveness on the task that it was meant to achieve and the productivity. This one is however extremely difficult to quantify on the basis of the information collected in the report.

Reconfiguration of the cultivated areas

The regular analysis of the results of each area had led to changes in the organization of the cultivated areas, in particular in the Mandala. The results of the first year show that the plots were significantly less productive than those in other areas. This result was logical: located in Zone 2, the Mandala was, therefore, less maintained and cared in a less intensively way (perennial and long cycle crops, fewer crop cycles). The difference with other areas, however, appeared to be much larger than expected. The discussions between the market gardeners revealed that one of the reasons for this was the way it was set up, not very ergonomic for such a complex area. In August 2013, it was decided to carry out a reconfiguration of the Mandala center to allow a better passage and easier follow up of the crops (see Figure 8). This configuration gave, as a result, a reduction of the cultivated area which went from 378 to 320 m^2.

This reconfiguration of the Mandala carried out in the summer of 2013, resulted in an increase of the measured workload. The time spent on the redevelopment of the plots within this studied area was recorded as well. It should be noted that this reconfiguration does not change the "permacultural status" of this area, which remains included in Zone 2 and which will be used mainly to grown long cycle species, perennial and aromatic crops that require less maintenance.

On the left, the mandala, summer of 2013: the mounded raised beds with an arc shape lead to a "labyrinth passage" which doesn't favor the crop monitoring.

To the right, the mandala after the reconfiguration: the mounded raised beds radiate out from the center, creating easier passage and crop monitoring.

Figure 8: The Mandala before and after its reconfiguration in August 2013

The reconfigurations of the cultivated areas also concerned the greenhouses. The small greenhouse was enlarged. On the contrary, the installation of the chicken coop in the large greenhouse led to a reduction of the cultivated area. Ultimately, the cultivated areas under the greenhouses went from 420 m^2 in 2013 to 450 m^2 in 2015. On the other hand, the Pommiers and Rivière areas remained almost unchanged. The total surface area included in the study went from 1,032 m^2 to 1,000 m^2.

Within our system, we have therefore, a reduction of the cultivated area in the Zone 2, which is the least productive, and an increase of the surface of the greenhouse which is the most productive. Having an impact on the productivity values measured in 2014-2015 and the surface areas of the period of 2013-2014, by comparing the results with the ones observed in the period of 2014 – 2015, we can estimate that **the reconfigurations of the cultivated areas contributed to 27 % of the total increase in the production.**

Hotbeds: a farming technique that extends the production period

The Bec Hellouin organic farm installed the first hotbeds in the winter of 2014, drawing on the experience of the Parisian market gardeners of the nineteenth century.

The hotbeds were tested in the greenhouses and open fields on a section of the "Pommiers" area. Out in the field, the installation of tunnels nantais (a thermic film that covers the crops to protect them from cold climate) in the hotbeds have led to a highly effective system thanks to the east – west orientation. In the middle of January, when the weather was still cold, crops benefited from the calories generated by the composting manure and also from the greenhouse effect created by the tunnel nantais that captured the sunlight thanks to its orientation and to the absence of foliage of the surrounding trees.

In the greenhouse, the hotbeds have significantly increased the temperature, helping to accelerate the development of the crops beyond the beds concerned. This effect was reinforced by the construction of a chicken coop at the heart of the greenhouse, which contributed to an increase in temperature to a small extent thanks to the metabolic heat production of the animals, and mostly from the manure decomposition in the chicken coop. These advantages are however mitigated by the labor cost which required their installation, as we shall see later. After the experimental phase of 2014 (165 m^2 cultivated), in 2015 the new hotbeds were limited to an area of 46 m^2, dedicated mainly to the production of seedlings for early vegetables.

The agronomic benefits of hotbeds were however well demonstrated by the results of the study. The earnings caused by the early maturity of the crops are clear since it permits to diversify the vegetable baskets early in the season. This effect is illustrated in Figure 9, where the values are calculated on a rolling month, the value assigned to any month corresponds to the production value of the previous month.

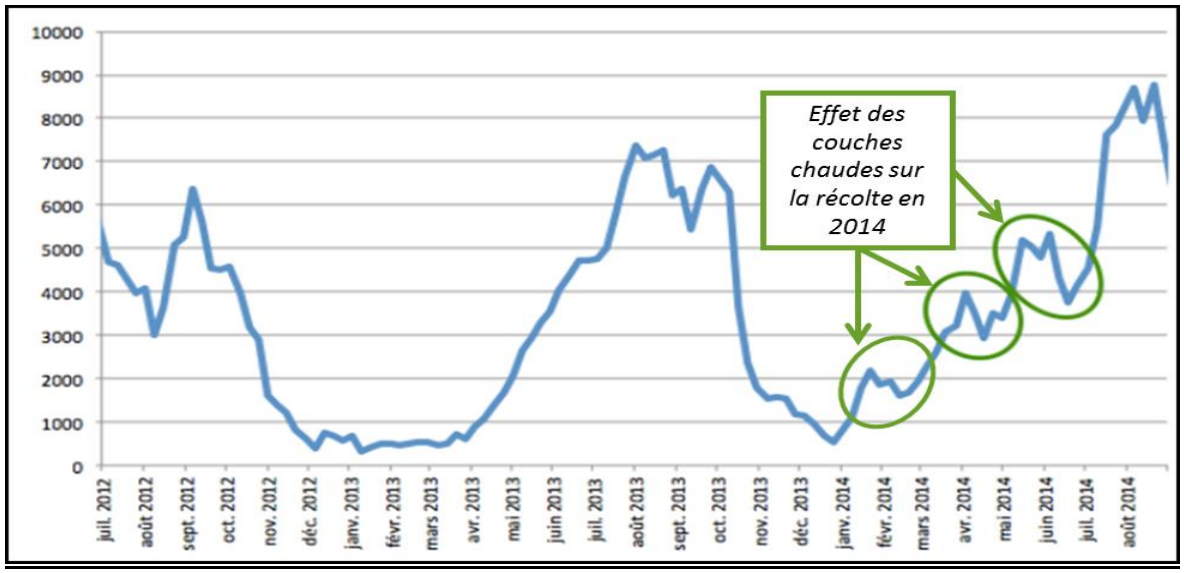


Figure 9: Impact of hotbeds on the production (value in euros over a rolling month)

The diversification of market opportunities, a key factor for increasing the production

Between the beginning and end of the study, the farm businesses had evolved. The most remarkable fact is the increase in the proportion of sales to "high end" restaurants that went from 14% to 27% of the products of the study area (Figure 10).

That increase of market demand of particular products has allowed further diversification of the crop species. Among these, some edible flowers, aromatic, annual, perennial, have yielded better results on some plots where they have been implanted, especially in the Mandala. But above all, these particular products have helped to further increase the intensification of production.

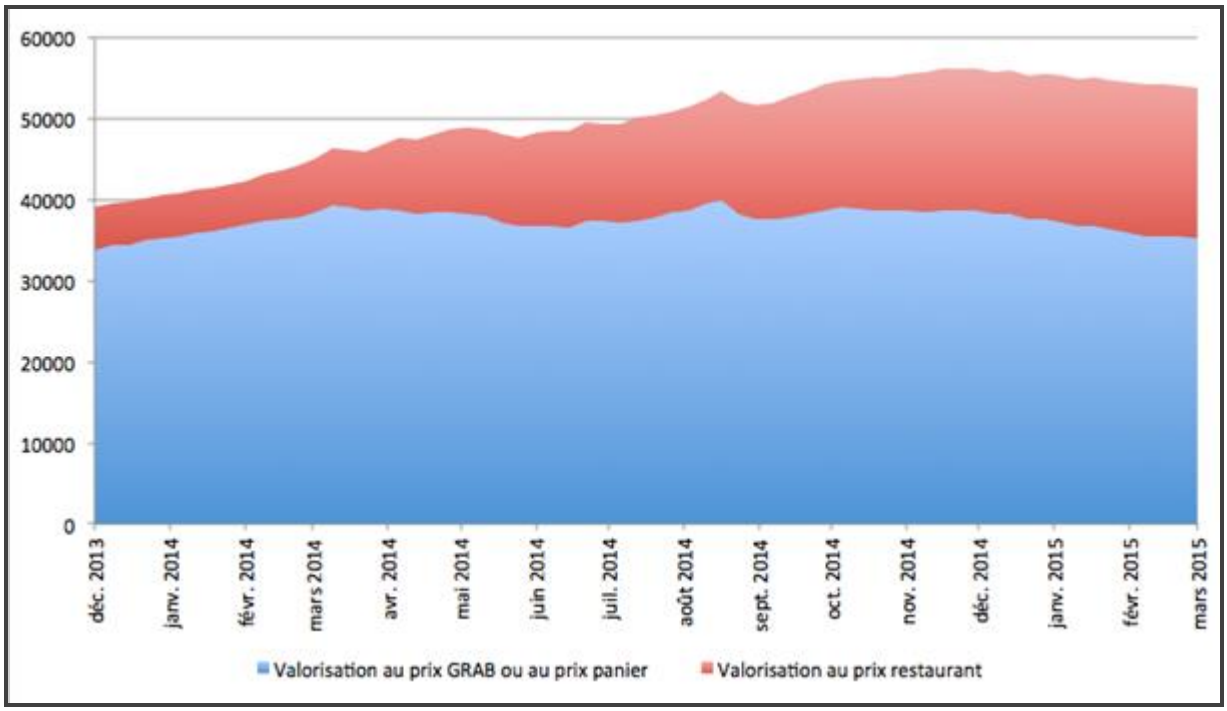


Figure 10: Harvest value over one year rolling (in euros)

The restaurants require a large quantity of “mini-vegetables" (fennel, carrots, sprouts of various kinds, eggplant, zucchini, lettuce, turnips, etc.) and vegetable flowers (zucchini, peas, etc.). In the case of "mini-vegetables" (cabbage, fennel, greens, turnip, leek, etc.), their density may be much greater than when these are brought to their “normal” term of development. In a single bed the number of vegetables will be much more important. These vegetables are usually sold individually or in bundles. The selling price of these vegetables is generally lower at that stage than at full “maturity”. But the quantity more than compensates the price differences in terms of value per m^2. On the other hand, the

crops harvested before full maturity would make room to the following crops. The bed comparison analysis shows that the introduction of these "early" crops has no significant effect on the number of crops for other farmers markets that succeed (or overlap) each other during the year. It is as if one introduces an additional crop in the year; the intensifying effect is undeniable.

There are other "special" products that are taken from plants (squash or pea blossoms, baby zucchini and eggplants, etc.) or within plant communities (carrots, fennel, etc.) intended to provide full maturity vegetables. The effect of these harvests have not been studied, and it is difficult to judge by comparing the plots where these samples were taken from with the other plots: the variety of successions and potential associations don't allow any comparison between two beds that have the same crop at the same time. But it is quite possible that these practices "of valued thinning" eventually had little or no effect on yields in full maturity vegetables, or may have even helped increase them. Consequently, it is not unreasonable to consider them as a particular form of intensification.

To summarize, we can describe these "special" productions as "revenue passengers" in a system designed primarily for "ordinary" vegetable production, sometimes also intended for restaurants. **These particular vegetables, intended exclusively for restaurateurs, contributed to 46% of the revenue increase recorded between the start and the end of the study.** Their introduction into the cultivated beds did not affect the production intended for other markets, which remained fairly constant, although their surfaces were reduced: all products valued towards restaurants are not "temporaries" of the "customaries" crops, and part of the cultivated surface has been specifically assigned to them, thereby reducing the cultivated surface of "ordinary vegetables".

The intensification of the cultivated areas is the key to the productive performance

In conclusion, we can say that the increase of the production at the farm is attributable to a combination of multiple factors, all directed towards the intensification of the production, the intensification being herein understood in its original sense as an increase of productivity per unit area. The last two are still in this particular case, the most important are:

- ***More attentive care to the crops, that require an increase of the market gardening skills.***
- ***Improvement of tools and equipment.***
- ***Better management of intercropping, relay cropping and densities.***
- ***Introduction of new cropping systems, enabling longer production periods (hotbeds).***
- ***Reorganization of the cultivated areas in coherence with the objective of increasing ergonomics and, therefore, the effectiveness of the work.***
- ***Introduction of new products which do not affect the production of "common crops".***

The key factor of the economic efficiency of Bec Hellouin Farm is the intensification and the production in the unit area. The price of products has in fact almost no influence on the increase observed in the "GS" of the studied area. However, the flexibility offered by the diversity of the markets in which the farm is positioned is undoubtedly a key point of its success. The issue of "market strategy" is clearly essential in the conception and management of organic micro-farms.

The key point to remember, however, is that of competence: the significant outcome as from 2014 is primarily the result of the experience acquired of market gardeners, in their understanding of the agronomic and ecological context of their farm, in their technical choices as in the management of the crops. This experience has been built up in a permanent learning process made of essays and error analysis. The implementation of the study has most likely accelerated this process, but it is not enough to explain it.

Working time

Annual working time

The annual working time of the studied system (Figure 11) was approximately 1400 hours in the gardens for the first year (June 2012 - May 2013). It rose about 2100 hours for the second year (June 2013 - May 2014) to go down to 1600 hours last year (April 2014 - March 2015).

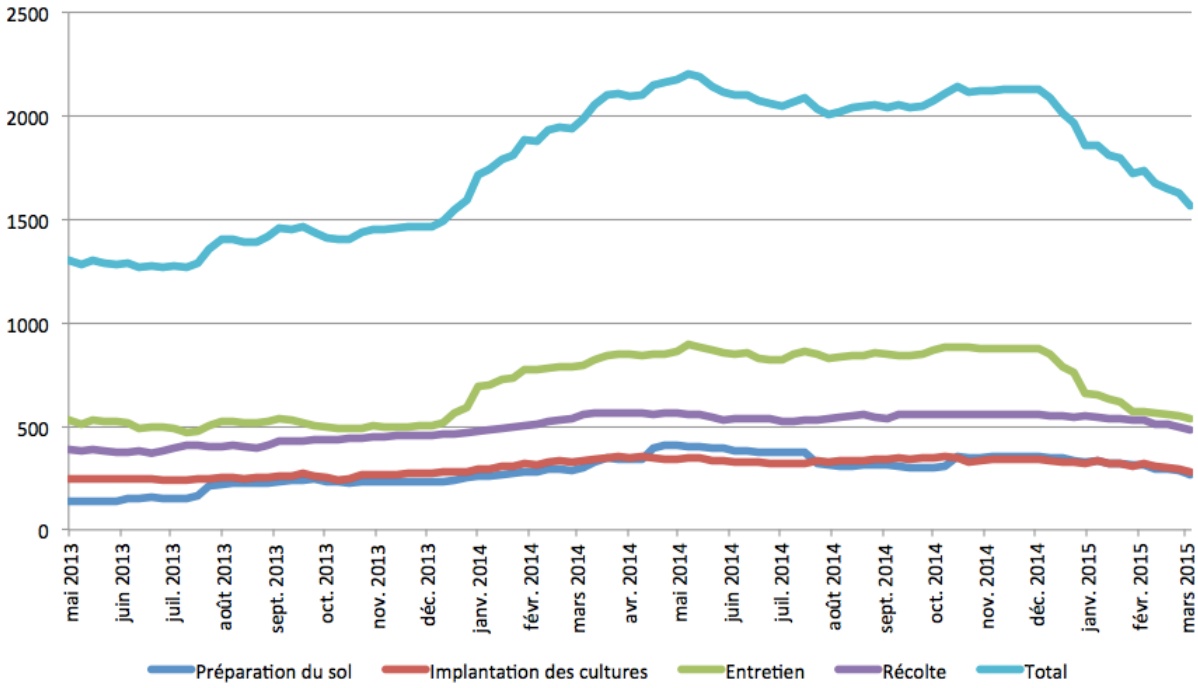


Figure 11: Working hours accumulated on 52 rolling weeks

The increased workload recorded between January and June 2014, whose analyses were detailed in the report released in December 2014, can be attributed to several factors. The main reason is the reconfiguration of the Mandala area in autumn 2013, and especially, the setting up of hotbeds in January and February 2014. These different projects indeed caused an important work overload. The hotbeds were particularly demanding on labor (Figure 12). This explains why, despite the advantages of this technique, the hotbed installations were done on a much smaller scale in the winter of 2015. On 52 rolling weeks, the workload, therefore, decreased at the beginning of January 2015 (the time devoted to setting up the hotbeds in 2014 which was a total of 383 hours), which gradually decreased throughout the 52 weeks period.

Beyond this one-time effort invested in the hotbeds, the workload increase should also be attributed to the general crop intensification and reconfigurations of the cultivated areas, expansion of greenhouses where the crop maintenance is higher and the reduction of the Mandala areas where the crop maintenance is lower. The latter factor, alone, led to an increase of approximately 110 hours of annual working time.

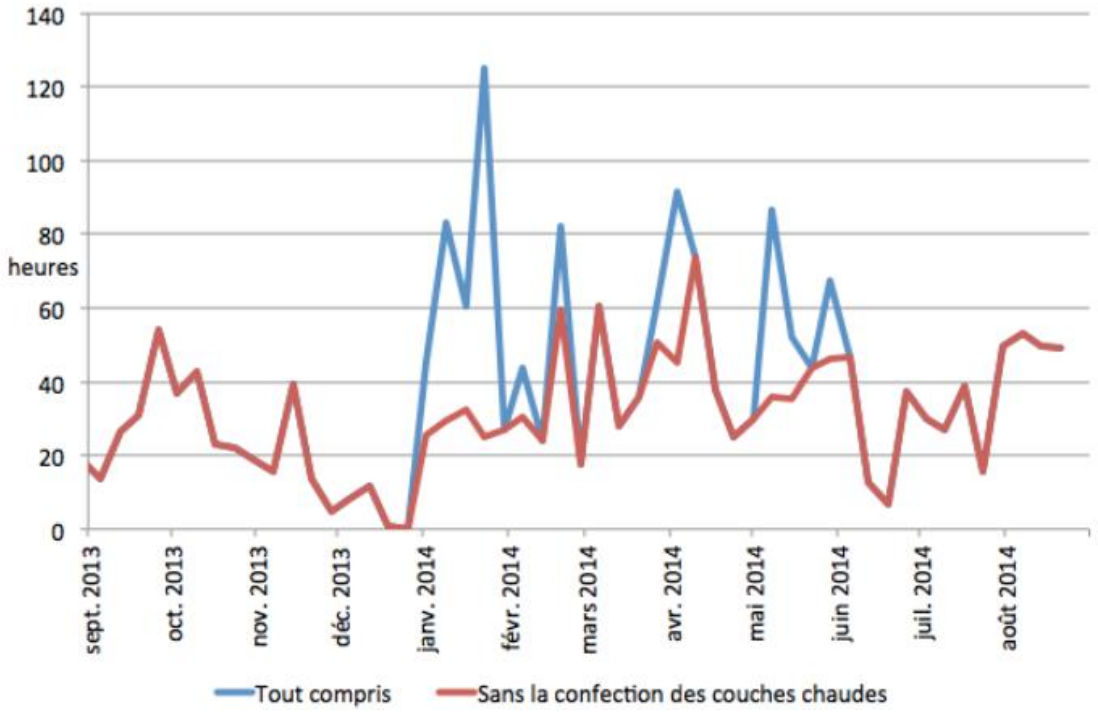


Figure 12: Weekly workload from September 2013 to August 2014 and impact of hotbeds set up

Intensification of production and workload

The consequences of the intensification are many: increase in time spent on reshaping the beds and soil preparation (because of the increase in the number of crops on a single bed), increase of the transplanting time (due to their density and the increase of the number of crops on a single bed) and, to a lesser extent, sowing; consequently increasing the harvesting time. It is also reflected by an increase of crop maintenance, weeding in particular. Finally, the different factors (reconfiguration of cultivated areas, hotbeds, greater intensification and further care for specific crops) which help explain the high productivity level achieved in the study area, lead to a workload that is hardly acceptable for one person.

In 2013, the situation remains acceptable: the number of weeks where the working time exceeds 35 hours, concentrated during the period spring/summer is still relatively moderate (Figure 13). At the farm, many people were likely to work at the same time in the gardens. This explains the very high peaks during certain weeks, often followed by quieter periods, where the total weekly work in the garden does not reach 35 hours. If there was just one person working, we could imagine that another work distribution would be established to smooth out the workload. The site developing tasks could also be postponed to the off-peak periods. Nevertheless, even in a year like this one where the level of intensification was not at its maximum, the workload would remain significant. Occasional help, or the support from a trainee, would undoubtedly by essential to smoothly overcome the most problematic periods which are from late April to late July. And it would not be easy to free up time, even just for a week of summer vacation.

In 2014, it is however absolutely possible to consider that a single person could handle the significant workload required by the high standard of productive efficiency targeted, as seen in Figure 13, which shows how the weekly workload in the gardens is just as important to consider as the annual workload:

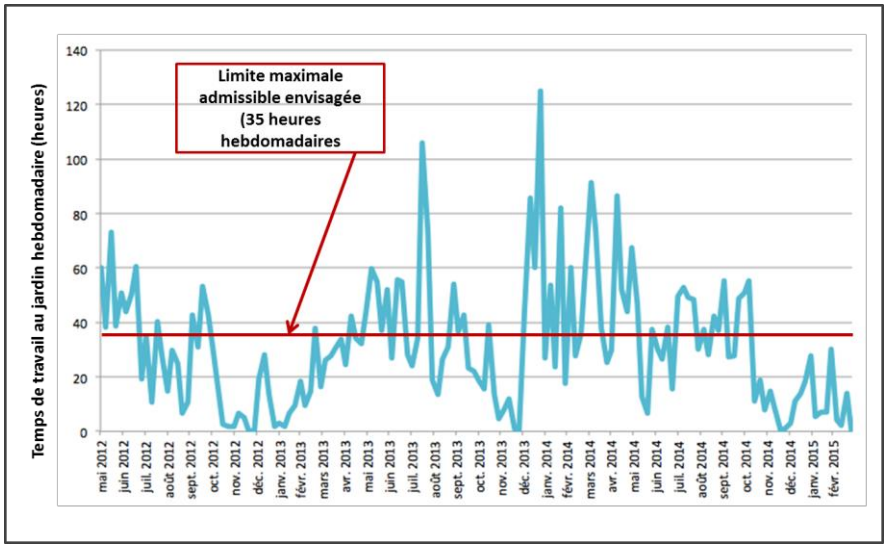


Figure 13: Weekly working time during the study

Degree of intensity and quantity of work

The study of the amounts of work invested in the different gardens shows that the latter is directly proportional to the degree of intensification. Figure 14 shows the results for the same period from 28 March 2014 to 28 March 2015 for which we had presented above the results of value produced per unit area. Note that this period does not include the making of the hotbeds in the greenhouse in January and February, which would have greatly affected the results. The time devoted to the set-up of the hotbeds in the Pommiers area, is, however, included in the work time calculation. The effect of such installations reported to the entire surface of the Pommiers 0.17 hours / m^2.

The Mandala, in Zone 2, demanded less work (0.85 hour/m^2 on average). The Rivière area demanded 1.21 hours / m^2, the Pommiers area, 1.48 hours / m^2. The difference between the two areas is largely due to the hotbeds in the Pommiers area: on the other plots, the average annual working time is only 1.22 hours / m^2.

It is logical that in the greenhouse the annual working time per m^2 is the highest: it has the highest number of crop cycles, with an immediate impact on working time (2.12 hours / m^2 on average). This is also the area where the time devoted to the different raised beds varies the most. This is due in part to the significant work investment spend on the construction of bins for the hotbeds, a task that can be viewed as an investment and not as a normal activity that only affected some plots. On the other ones, the work productivity, however, is still much higher than in open field areas (1.84 hours / m^2).

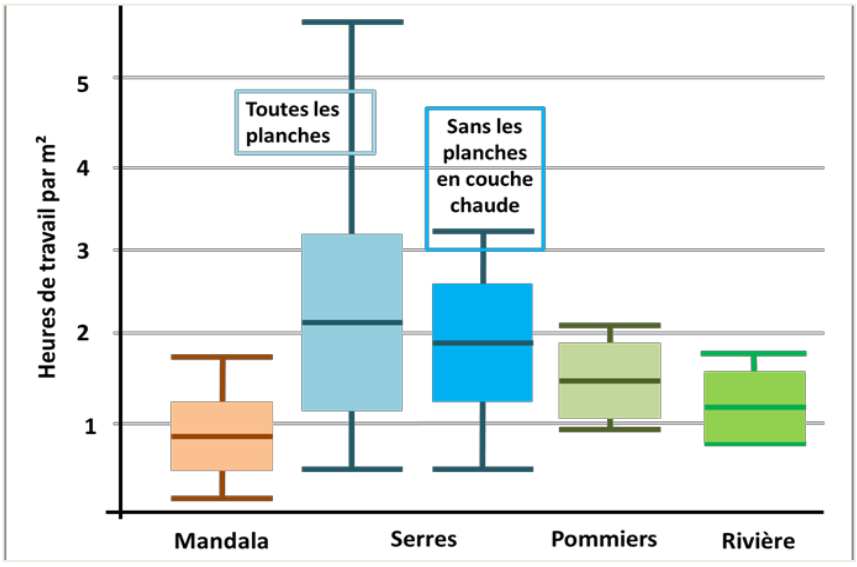


Figure 14: Annual working time per m^2 in the various areas
Period from March 2014 to March 2015

Note: This period does not include the installation of hotbeds in the greenhouse

Labor productivity and intensification of the cultivated areas

The hourly labor productivity, that is to say, the value of vegetables produced per hour worked, globally increased during three years as shown in Table 2. In the case of the greenhouse, the investments made to develop the hotbeds resulted in a decrease of such productivity (24 € / hour between April 2013 and March 2014, when the majority of the hotbed were set up, against 37 € / hour between April 2014 to March 2015, when fewer hotbeds were set up). We must remember though, that in this case there is an investment whose profit could be felt for years. Thanks to the hotbeds, the fertility of the beds increased and the ergonomics improved: since the beds are higher, it requires less bending forward. On the last period of the study, between April 2014 and March 2015, the labor productivity is fairly homogeneous among the various gardens (Figure 15): this is an average of 30€ / hour in the Mandala, 37€ / hour in greenhouses, 35€ / hour in Pommiers area, 32 €/ hour in the Rivière area.

	Year		
Area	**From April 2012 to March 2013**	**From April 2013 to March 2014**	**From April 2014 to March 2015**
Greenhouse	21	24	37
Mandala	12	17	30
Pommiers	31	31	35
Rivière	14	26	32
Global	**19**	**23**	**35**

Table 2: Evolution of the hourly labor productivity in the various areas during the study (Gross sales including value-added tax per hour of work in €)

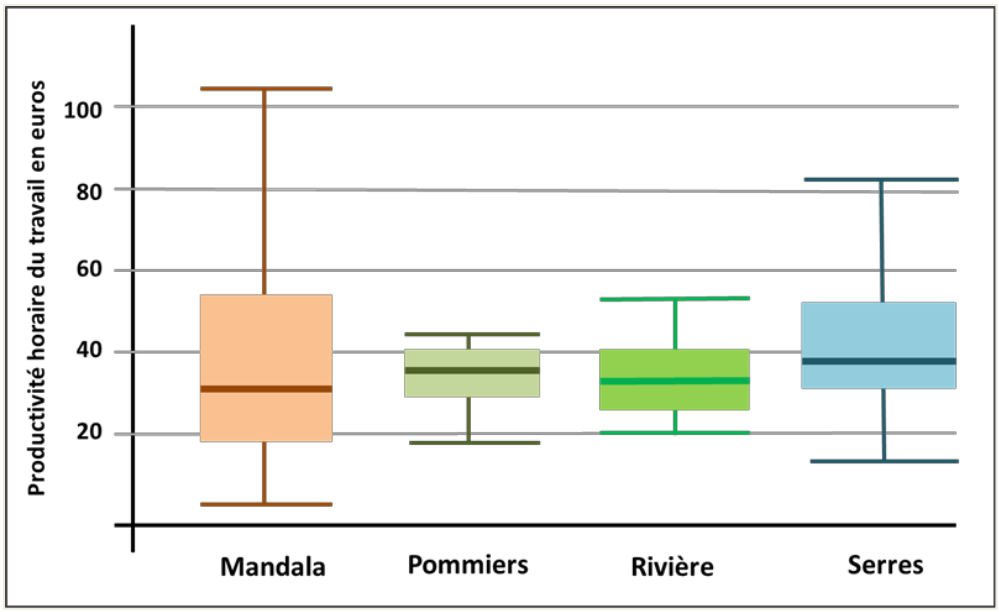
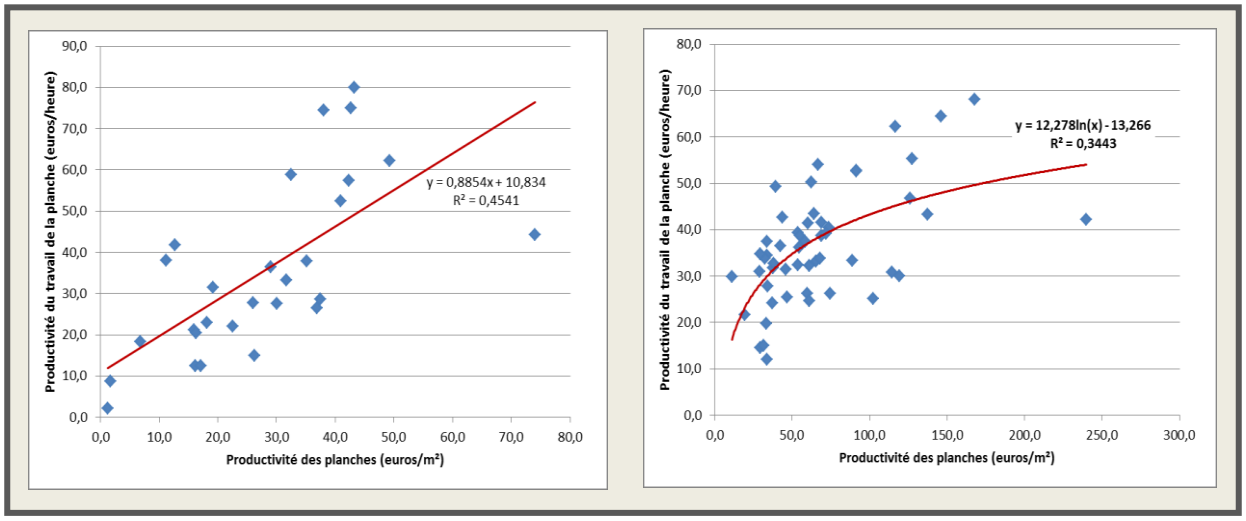


Figure 15: Labor productivity (euros/hour) in the studied areas, Period from 28 March 2014 to 27 March 2015

We notice that the greatest variabilities are observed in the greenhouse: the higher the level of intensification rises, further problems and failures are paid because they often occur after most of the work has been done as is the case for the Mandala. In this area located in Zone 2, the relationship between labor investment and production is particularly striking: the intensification of the production per unit area is associated with an increase more or less linear of the work productivity (Figure 16a). In the 3 areas of the Zone 1, this relation is much less clear and even nonexistent. The best adjustment is made with a logarithmic curve (Figure16b).



<u>Figure 16</u>: Relationship between the productivity on the surface area and labor productivity on the studied beds
(16 a, on the left = Mandala; 16 b, on the right = Areas of the Zone 1)

These curves show that there is a limit of intensification beyond from which labor productivity increased slightly, if at all, whereas the consequences associated with failure or incidents continued to rise, because we invested more work.

This intensification allows increasing the productivity per surface area, and thus the value of production of the farm. It is of course essential in order to ensure a basic level of gross sales on a small surface. But, **as soon as this basic level is ensured, it may be worthwhile to devote the available labor resources to less intensive and risky areas,** where the relationship between surface area productivity and labor productivity is optimal. In the case of our study these optimal surface areas correspond to the Pommiers, Rivière areas which are the best managed, that is to say the areas of the "Zone 1" open field" where the management is more effective, with several successive crops that have given good results and whose crops are highly productive with a relatively rapid development (in the study, the most emblematic of this type is probably the zucchini).

This question of trade-offs between labor and surface area productivity, related primarily to crop rotation and crop choice in these successions, is undoubtedly a key element to be taken into account in the conception and management of the gardens.

From production to income

This part of the work is largely taken from the article of Kevin Morel and François Léger titled « Can an organic market garden without motorization be viable through holistic thinking? The case of a permaculture farm *», available as open archive in the following address: https://hal.archives-ouvertes.fr/hal-01200636 Some of the figures presented in this section may be slightly different from those presented above. This is mainly to the considered time boundaries, herein the year calendar.*

The income modeling method

From the raw measured data (crops and working time), we conducted a modeling work based on the different hypothesis to estimate the income and working time of a market gardener who would work only on a giving surface area. The results presented are therefore the result of a theoretical modeling and do not represent the economic performance of the Bec Hellouin Farm that grows 4,500 m^2 of vegetables on a total area of 20 hectares. To estimate the annual gross sales, the marketed quantities have been multiplied by the price of vegetables. For the common vegetables, we used the average prices of organic vegetables sold locally in Upper-Normandy. We used the farm prices for uncommon vegetables which are not regionally referenced. The Costs, expenses, and taxes associated with this production have been deducted from the gross sales to estimate an income. These data were estimated based on the farm documents and discussions with an expert on market gardening accountancy. We considered a low cost hypothesis (LC): second hand equipment, basic storage/selling building and no delivery van (the whole production is sold at the farm) and (ii) a high cost hypothesis (HC): purchased new equipment, a more sophisticated building and a delivery van (which implies fuel consumption). The hypothesis (LC) leads to a higher maintenance cost because the equipment is not new. We chose to multiply the working time measured in the field by 150 % to take into account unmeasured commercial and administrative tasks. In fact according to conventional market gardening references for local markets, these activities account for a third of the global workload on the farm.

Scenarios that lead to an acceptable income in 3 cases out of 4

In 2013, the estimated GS was 32,788 € the cumulated global annual workload was 2006 hours that is 43 hours per week, which can be considered acceptable. Such work could be provided by a single market gardener working full time, benefiting from help in the busiest periods. In 2014, the estimated GS was 57,284 € and the annual workload was 3026 hours. This workload would represent an average of 58 hours per week for a single person, the market gardeners didn't agree with that. In 2014 the income estimates concluded that a market gardener worked 2006 hours like in 2013 and that an extra 1020 hours were provided by an paid employee with a salary of 9.61 € per hour (French minimum wage). In a vegetable farm, the extra work could also be provided by a voluntary (trainees or members of AMAP), which would have created a higher income. However, we chose to hire an employee to show that an acceptable income can be generated even without volunteer labor. For this employee the social security

contributions were of 42,3 % from the gross salary without any exemption. Indeed, these charges can be reduced to about 9% for the short term contracts of less than 3 months; but we didn't consider this hypothesis because it seemed precarious for the employees and, therefore, considered the 42,3 %.

With the low cost hypothesis (LC) the monthly net income was 1,132 € in 2013 and 1,571 € in 2014, both revenues were acceptable by the market gardeners. With the (HC) hypothesis the monthly net income was 898€ in 2013 (not acceptable) and 1, 337€ in 2014 (acceptable) as shown in Table 3 below.

For the presented 2014 scenarios, we must remember that if we include the employee remuneration, the total net compensation for the 1,000 m^2 rises to 2, 8651 over the year under the LC scenario, that means 9,47 € per hour worked, and under the HC scenario, to 2,5881 €, or 8,54 €. In 2013, the net hourly labor compensation was 6.77€ under the LC scenario and € 5.37 under the HC scenario. The difference related to the intensification is significant, but it involves more work.

Year	**2013**		**2014**	
Cost Hypothesis	Low (LC)	High (HC)	Low (LC)	High (HC)
Gross Sales (including valued-added tax)	**32,788**		**52,284**	
-Valued-added tax (5,5%)	1,709		2,986	
Net Gross Sales (excluding value-added tax)	**31,079**		**54,298**	
-Seeds and young plants	4,000		6,500	
-Fertilization, other supplies, and small equipment	1,500		3,000	
-Other purchases and expenses (water, electricity, fuel, equipment maintenance etc.)	6,000	5,000	6,000	5,000
-Property tax	100			
-Labor cost employer contribution (employee's salary in 2014)	0	0	9,802	
-Employer's contributions * (42,3% from the gross salary)			4,146	
- Social security charges and Insurance	4,000			
-Interest expenses (bank)	300	700	300	700
-Depreciation of the greenhouse (constant over 5 years)	800	2,000	800	2,000
-Depreciation of other equipment: irrigation systems, tools, delivery van (constant over 8 years) storage and selling building (constant over 20 years)	**800**	**3,000**	**800**	**3,000**
Annual net income	**13,579**	**10,779**	**18,849**	**16,049**
Monthly net income (before taxes)	**1,132**	**898**	**1,571**	**1,337**

*In the case of a short term employee, this rate can be reduced to 8,67%.

Table3: Income Estimates for a market gardener based of annual production and cost hypothesis (€)

What would happen if the workload of an employee (1,020 hours) was provided by a partner having an agricultural status, full-time, like in 2013, working 43 hours

per week (2,006 hours), would the total cultivated area increase in proportion to the additional time available (944 hours)?

If so, the cultivated area would then reach 1,350 m^2, the monthly net income would be 1,680 € under scenario LC and 1,520 € under scenario HC.

Market gardener micro-farms: a "competitive" model, subject to a sufficient level of technical and economic efficiency

Under the 2013 scenario / High level of investment, the attainable income (898 euros net monthly) is significantly lower than the level of private deductions proposed in the case study "*Creation of organic market gardening and direct sales*" of the Chamber of Agriculture OF Upper Normandy[4] (1,280 €).

It is lower, but in less significantly way under the 2013 scenario / Low level of investment (1,132 €), equivalent under the 2014 scenario / High level of investment (1,337 €), significantly higher than in the 2014 scenario / Low level of investment (1,571€).

Both of these models, case-type and micro-farm; correspond to an ideal situation well under control by experienced market gardeners, with comparable labor investment.

The micro-farms scenarios dictate that the entire workforce available for the farming production should be invested in a much intensified space. It is not necessarily the case for a “real permaculture farm ", where attention should focus on the other zones, including the less "income producing" areas which have an irreplaceable role in the ecological functioning of the farm and that ensure its resilience and sustainability.

Nevertheless, this modeling work suggests that the hypothesis which we intended to prove is verified: *it is possible to produce a significant yield on a small area, cultivated mostly manually, and to generate enough profit to ensure an adequate income to someone with an agricultural status.*

[4] http://partage.cra-normandie.fr/bio/castype-1.pdf

From the study to permacultural micro-farming

The 1,000 studied m² are part of a whole ecology

The study focused on the production carried out on 1,000 m² cultivated. But these 1,000 m² should not be considered self-sufficient. There are in constant interaction with their environment, and have been conceived and set up to provide ecosystem services necessary for the proper operation of the system. These interactions are essential to ensure fertility, thanks to the transfer of materials collected on the farm or in its immediate surroundings: If it was not for the nearby equestrian club, there would not be manure and hotbeds. The trees, hedges and pastures surrounding the studied area constitute habitats for diverse species that contribute to the regulation of crop pests. The ponds, river and buildings help create a more favorable microclimate for the vegetable production.

It is vital that this environment exists and that these links are created, either within the farm itself or in interaction with the nearby territory. In other words, it is necessary to look beyond the cultivated beds and the vegetables and to consider the system as a whole, with its components, ecosystems (hedges, ponds, grove, etc.) and the necessary infrastructure for the market garden activity (toolshed, washing zone, farm shop etc.). The 1,000 m2 cultivated are the heart of the system, which are the most well-kept (and from this point of view the greenhouse is “the heart of the heart”) but there are just the heart.

The intensification choices dependent on the economic context

The results obtained on the 1,000 m² of the study are astonishing, So much; they seemed high in comparison with generally recognized standards for organic farms oriented towards local markets. These "astonishing" results are explained by the high level of intensification of the studied beds. A level achieved thanks to the used techniques (intercropping, relay cropping, hot beds, etc.) as well as by the diversity of the crops. On average, 76 kinds of products have been grown annually in the gardens: 17 types of aromatic herbs and edible flowers (7% of GS), 16 kinds of vegetables - fruits (41% of GS), 11 types of root vegetables (20% of GS) and 32 types of leafy vegetables (32% of GS).

This diversity offers many possibilities of intercropping and crop successions, which contribute to the intensification, creating a heterogeneity which is probably very favorable to the "immune systems" of the cultivated ecosystem, therefore, the health of crops and their productivity. This is only possible thanks to the diversity of farm markets which absorb this variety of products.

On a system that would only market its products in the form of vegetable baskets, some of these products which allow reaching a productivity level in the area dedicated to the study, would not necessarily find their place in the market. In order to fill these vegetable baskets, there will not be enough products, to supply to the customers, even the “engaged customers” during certain seasons. On 1,000 m², there are few semi-perishable vegetables that are part of the vegetable baskets sold by the Bec Hellouin Farm. These are

produced in other areas or purchased from a nearby organic farmer when these are running out.

This is where the idea of micro – farming in partnership takes all its sense, it allows to better distribute the available workforce between a much intensified area, just like the one studied, and the less intensified areas where other types of vegetables will be produced. It offers more flexibility of adaptation to “conventional" marketing strategies, based essentially, on the sale of vegetable baskets as part of a nearby commercial network while keeping a micro-farm model in a much smaller area than those recommended for the installation of organic farms for local markets that require greater investments.

The micro-farm appears to be a realistic economic model for project leaders without a land base and with limited investment capacity.

To think about permacultural micro-farming beyond the study

The 1,000 m ^{2} of the study are not " the farm " and do not tell us about " the farm " but only about the possibilities and interest that a high level of intensification could offer, based on crop techniques that demand little input: with the exception of the hotbeds, the organic material used for the crops could only come from other areas of the farm (Zone 4), which is only possible if these exist.

The design of a permacultural micro–farm cannot only be a focus on the studied intensive core. It must consider all the areas which will ensure the proper metabolic (the flows of materials within and between zones) and immune functioning (positive biological interactions within and between zones) of the farm seen as an ecosystem. These agroecological dimensions should be studied in depth. That’s one of the objectives envisaged for the pursuit of the collaborative research work undertaken since 3 years ago.

The study gives us valuable information on the productivity at the intensive core of a permaculture farm and the ways of which it builds itself. A more thorough exploration of the considerable amount of data collected would allow us to go deeper into this knowledge.

This information is very important in order to prepare the main considerations for the design of an organic vegetable micro-farm: what trade-offs make in the allocation of the resources, areas and labor, primarily in the different zones which are an essential part of such farm and where the question of the relation of the area and labor productivity is, as we have seen, essential:

- *At the intensive core (in terms of area productivity) labor intensive;*
- *Zones devoted to the production of bulky crops often difficult to carry out exclusively with manual labor techniques (e.g. potatoes);*
- *Areas dedicated to the additional production (fruits, small livestock)*
- *Areas reserved for the production of ecosystem services, material sources and favorable interactions with other areas (micro-climate regulation, biological control of crop health, etc.).*

The trade-offs can not only be made by taking into account the ecological context of the farm but also the economical context, the existing or potential markets where the farm can position itself, its social context, the aspirations of the project leaders whether personal or directed towards their territory, their networks, the expectations expressed or latent of the territory in relation with the farm networks.

Conclusion

Each project is unique and has a unique location. The results of the study in any way account as references or recommendations that should be applied literally. They just point out a small portion of a horizon of possibilities. In this report, we wanted to stay as close as possible to the genuinely produced data, so that everyone will have access to and could interpret it for their own. The study conducted at Bec Hellouin organic farm has generated much debate and controversy and will undoubtedly continue to do so. The idea was exactly to create and feed the debate and certainly not to settle it.

Th point of view of a naturalist biomimtist

Gauthier Chapelle (*Biomimicry-Europe)*

I did not see the farm "with my own eyes," since the first time in that (cold) month of June 2013, before returning back in early July. My testimony is fresh; less "objective" more anecdotal, "qualitative" subjective; and, therefore, complementary? I decline in several reactions, a mosaic taken with the usual precautions, but can, however – I hope – provide additional insight to appreciate an initiative based on and reflecting so well the complexity of the living world.

My first reaction will be based on my naturalist passion: I was immediately struck by the significant presence and diversity of wildlife present on the farm (not to mention the diversity of domesticated species and varieties). If this biodiversity is partly based on the assembled habitats of this small area (running and stagnant waters, meadow, brush, woods, etc.), I would like to share two observations that can give a minimum of insight to that which is first of all, an instinctive feeling.

The first naturalist observation concerns the birds, particularly a sub-group of the sparrows, a granivore family par excelence, that of finches (one of the best known is the lark). To my surprise, only two days in the middle of June were enough for me to observe 7 different species,[5] that is all the theoretically possible nesting birds of this part of Normandy. All on a viable farm operation! And in a context of increasing scarcity of the once common species (such as the Linnet and Pyrrhula[6]).

The second relates to the insects: we notice the presence of mayflies and several species of dragonflies, including the calopteryx virgo, which verifies the ecological quality of the aquatic environment of the farm. But I was especially challenged by the abundance of a very special red and black beetle called the 'Clairon des abeilles[7]'; adults were present on many different flowers like in the vegetable gardens and forest-garden, and were busy nibbling and pollinating but something more significant is that their larvae are parasites themselves of several solitary bee species, which is obviously a sign of their massive presence on the whole farm. When one knows the importance of the complementary honeybees in terms of pollination, one can only rejoice. Beyond these initial observations, I can only recommend refining the knowledge and evolution of this fauna present in the different plots: There is work to do! And that would certainly enchant students.

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[5] The Chaffinch (*Fringilla coelebs*), the European Greenfinch (*Chloris chloris*), the Goldfinch (*Carduelis carduelis*), the Linnet (*Linaria cannabina*), the Canary (*Serinus serinus*), the Bullfinch (*Pyrrhula pyrrhula)* and the Hawfinch (*Coccothraustes coccothraustes*).

[6] A decline of 70-60% in France over the last 20 years.

[7] *Trichodes apiarius*. For a quite anecdotal comparison: during two days in June, I have seen at least twenty individuals. Three times more than all the Belgian observations recorded at www.observations.be between June 1 and July 15!

My second reaction is related to my agricultural path experience, concerned about climate change and our collective addiction to fossil fuels. Even if Charles has already evoked that in his « Farmer's point of view », I would like to emphasize this: without being an expert on the subject, I think I have not yet seen or heard anything in our northern countries, on this scale, which goes so far towards the direction of market gardening weaned from oil. Certainly there is still some way to go, considering the use of plastics and sometimes some mechanization[8], but for the first time, I felt that this vision did not seem unattainable. It remains to enhance it!

This brings us also as to the importance of the ecosystem services provided by this market gardening approach. Beyond their enumeration by Charles, I think it would be useful to give a biophysical quantification in the future. Not so much to convert them into euros (can we get out of this logic of excessive financialization? Wide open question ... for a forthcoming report?), but to simply highlight them and contrast this regenerative approach based on the flows (like all other ecosystems, as the biomimetics would say) with the approach of industrial agriculture, which is extractive and is gradually exhausting the stocks organic fertility, carbon, phosphorus, fossil fuels, biodiversity, etc..

There would be still much to say. I shall add another point which seems to me at least as important as the others: why did I want to encourage more of my compatriots to visit[9]? Only one word: the beauty of the place. It produces an abundant quality of food, diversity and is increasingly beautiful!!! What else can we wish for?

July 18, 2013

Two years after my first synopsis, the Bec Hellouin Farm holds up on to its biodiversity carrying capacity.

[8] But the biomimetic solutions are or will be available to address these two issues: the plant–derived bioplastics sector is evolving, even if it still has to be bio-sourced from an regenerative and nonindustrial agriculture; same thing for potential biofuels produced directly at the farm, as is done already elsewhere (see in particular the Land Institute's work on the Sunshine Farm project, http://www.landinstitute.org/vnews/display.v/ART/2000/08/01/377bbca63)

[9] This July 5, we were 12 Belgians to have made the trip to the farm, including one representing the innovation support in the Brussels region for urban agriculture.

Let us specify, that the farm has not yet been subject to systematic and rigorous studies until now, a gap which will be filled by certain groups in the new study that starts in autumn 2015, for instance on birds in partnership with the LPO (League for the Protection of Birds), on solitary bees under the direction of Dr. Nicolas Vereecken of the Free Universite of Bruxelles and on ground beetles (predatory beetles among some slugs) by Eskani Siruguet. The specific diversity of other groups would probably worth the detour like the Odonata (dragonflies), the micro-Hymenoptera (including parasites of aphids) or the annelids (earthworms).

For the record: it is always intriguing and amusing that a few even shorter visits in 2013, allowed me to add three new bird species which are again significant for a farm. The first one was the little owl (which was already known) which benefits from the diversity and abundance of insects while benefiting from the presence of old trees for nesting.

Most notable are the others, both nesting passerines and insectivorous: the common redstart, inseparable from the presence of trees, observed in family at the farm in August 2015, and whose populations have considerably become scarce (55 to 70% in Europe over the last 40 years) following the droughts in the Sahel and the intensification of agriculture; and the spotted flycatcher who was in the process of feeding their offspring in July 2014 and again in August 2015. Once fairly common, it has also showed a sharp decline in recent decades, due to a loss of habitat and the intensive use of pesticides.

October 14, 2015

Gauthier Chapelle is a Naturalist, Agricultural Engineer, Ph.D. in Biology and father. Co-founder of the NGO Biomimicry-Europa and the sustainability consultancy Greenloop, in Brussels, based on biomimetics.

Meanwhile, on the side of the market gardeners...
The study seen by the farm team

Charles HERVE-GRUYER

The study « Permacultural Organic Market Gardening and Economic Performance » was the opportunity of a unique collaboration between agronomists first and foremost François Léger and the market gardeners, in a climate of great listening and mutual respect. It's as a gardener that I am speaking without any scientific claim. We know that this report will be read by many of our colleagues so it is to them that I am addressing in particular. The points covered in this text generally coincide with those of the scientific report; the differences of treatment naturally reflect the different positions of scientists and market gardeners around the same object of study. On the bottom, we are perfectly in sync.

Agronomists and market gardeners, we were both aware of the opportunity that represented our differences. The Bec Hellouin Farm was essentially created in an intuitive way, with the desire to meet our needs as naturally as possible, giving a large place to the quest for beauty. The will to progress on the technical level came only later on. The agronomists have led us even further, by teaching us to take an objective and scientific look to our gardens. It is probably this combination of idealism and creativity, intuition and rigor, which gave birth to the bio-inspired system that characterizes the farm today.

There are no words to describe all that François, Kevin, Sacha and the other researchers who have driven this work have taught us. The heavy constraint that we imposed on ourselves of having to record and describe each of our actions in the gardens for many years was highly rewarding. François always allowed us total freedom on our cropping practices, which did not prevent to give rise to long debates on the relevance of such or such approach.

At the end of this study, the important mediatization of our farm probably distort the perception within the profession: for some, it represents an inspiring "ideal", while it exasperates others (which we understand!); it even happens that we are accused of inaccurate readings, so much the results of the study stood out from the techno-economic data derived from more conventional approaches to organic gardening. We are neither models nor fantasists, just market gardeners passionate about their work, animated by a sincere desire to share it with their colleagues at the risk of exposing themselves to their judgment. Together we want to find solutions to contemporary ecological and social problems while alleviating the often hard working life of the organic market gardeners.

At the beginning: the key issues

Perrine and I acquired the status of farmers in October 2006 without any training. During the early years, we work all our gardens with animal traction (in 2015, part of the farm is still conducted with animal traction). At the end of 2008, we encountered permaculture and the permanent raised beds concept, and integrated into our practices the work of Eliot Coleman and John Jeavons over the next two years. We discovered the legacy of the Parisian market gardeners of the nineteen century, which remains for us a subject of study, as well as the practices coming from Japan and Korea like the cultivation of effective microorganisms. We combine these diverse contributions and seek coherence between these practices.

When agronomists from different continents began to visit our farm in 2010, we were still not very developed in our approach. Our main gardens were still being created. At first we used permanent raised beds and mounded raised beds and then introduced flat beds (Coleman) adapted to the multi-row precision seeder. The heart of the farm, of which 1,000 m^2 would become the object of study, was outlined in its current form. The soil was very poor and was object of attentive care.

At that time, when agronomists, market gardeners, experienced gardeners and among them some of the "founding fathers" of organic farming started to visit the farm, they were usually challenged by our gardens. Contrary to our fear, nobody laughed at us: he is indeed growing vegetables! Even though the crops were carried out manually in an intuitive way and let us admit it, often in a messy and erratic way, there were productive throughout. Despite our many mistakes and our lack of technical expertise, in those years we were producing over 100 AMAP vegetable baskets, including in winter, on a small surface area, manually. The researchers were challenged by the permaculture approach which reveal itself to be natural, minimizing the use of fossil fuels and nevertheless effective. Could it be the beginning of a solution, a way to explore and to imagine a post-oil agriculture – an *agriculture du soleil*? (solar agriculture).

We were however confronted with real questions and struggled on issues that could have led our project to ruin. The absence of references was leading us at the edge of exhaustion. Our main question was: *which is the surface area that can be effectively cultivated manually?* Without indicators, our gardens were too big compared to what we could really grow and because of the lack of care the beds were full of weeds and we lost crops. We really had no idea of the economic relevance of our approach: in the absence of an analytical accounting, we did not exactly know the value produced; in addition, the work performed by the many trainees came to blur even more the visibility.

For all these reasons, in the spring of 2011 along with François Léger we came up with the idea of conducting a technical and economic study of the system, the central question was to determine the optimal area that can be grown entirely based on manual labor; based on our experience and our readings situated around 1,000 m^2 cultivated. As stated in the scientific report, it is important to determine, for that surface, the number of hours invested and the value of marketed production. These data will address the question: *Would 1,000 m^2 cultivated based on manual labor and by using the approach developed at Bec Hellouin, support a viable activity in terms of income and workload?*

Novice market gardeners

In late 2011, at the beginning of the study, Perrine and I had only five years of experience. In Addition, we were both relatively few working in the gardens and got caught by the rapid growth of our training activity: the eco-center was completed at about this time and from the opening we have welcomed several hundred trainees every year. Bec Hellouin received numerous demands, fast (too fast?) the farm was identified as an innovative, too many demands in relation to our response capacity. The role of Perrine and I was essentially to manage, advise our market gardeners and to try to fit in interesting practices for the gardens that we could gather in our researches. Throughout the study, the crops were mainly carried out by a team with little or no experience but motivated to go forward. We hereby thank the perseverance and professionalism of our colleagues, who have spent 40 months (it is nothing!) with a notebook in the pocket and an eye on the watch. They took note with conscience tens of thousands of data: Jean-Claude, a builder who built the eco - center became a gardener, Yohann, having just acquired the BPREA (Professional Diploma in Agricultural Operations Management) was quickly promoted to chief of crops, his successor Thomas, trained at the farm in market gardening, Teddy, trained as well at the farm and Jean-Pierre, a long-term unemployed who spontaneously came to help us was hired in 2015. Whether builders or coming from the world of catering, the workload did not scare them.

This team comprised of people with diverse strong personalities, whether coming from the rural world or NIMA (not coming from the agricultural world), was able to compensate for their limited experience with curiosity and workforce. It is to their credit to emphasize, that the good results of the study were not obtained by practitioners with a long career as market gardeners!

Barren soil

These results are not the fruits of an exceptional fertile soil, on the contrary: our valley floor has only a thin topsoil layer (15 to 20 cm), essentially silty, excessively calcareous, with a very low coefficient of nutrient fixation. The two series of Herody soil analysis performed before and after the study show that the original soil has changed little over the years; our crops grow mainly on a portion of the anthropological soil layer[10], built thanks to the raised beds and the soil amendments like compost and repeated mulch, on top the original soil. This soil tends to compact quickly and it holds little water. For all these reasons, every year we discover more about the importance of mulching, and, therefore, the need for the organic matter to achieve it. Fertility must be constantly maintained, the intensity of flow compensation of the reduced or little available stocks.

[10] Anthropogenic soil, anthrosol (FAO-UNESCO soil classification): Soil strongly modified by man.

Relatively speaking, this situation is a reminiscent of the context of tropical forests, where vegetation is lush despite of having a soil that is constantly leached and not very fertile, it is the intensity of the exchanges between multiple ecosystem components that compensate for the low nutrient availability. It is indeed an **agriculture based on the bioavailability and flows rather than on the stocks.** This perspective is part of the dynamics of life. In this sense, it is permaculture, because it suggests imagining human settlements based as much as possible on natural ecosystems.

Being able to obtain abundant crops on a type of soil a priori unsuitable for agriculture (according to archeologists, our valley has not been cultivated since the Neolithic) brings hope: In the future, humans will have to feed themselves by valuing the largely degraded and desertified land.

The numerous experiments

Throughout the 40 months of the study, we tried various and sometimes risky experiments. Some were successful, for example combining the approach of Eliot Coleman and that of the Parisian market gardeners. Coleman has developed a multi-row planter that allows in a return, to sow 12 rows of vegetables on a bed of only 80 cm wide. But he does not practice intercropping. We tried a combination of carrot / radish, to which we sometimes added lettuce or cabbage; 24 or 25 rows of vegetables coexisted on a bed! This very classic association in the gardens of the nineteenth century, proved to be relevant.

By gaining confidence, we have tried, over the years even more audacious associations (the out of the ordinary one was probably to plant in the greenhouse in early January a row of peas on trellis, two rows of early potatoes, two rows of lettuce and radish seedlings in 80 cm.....In our context, the 4 crops were successful!).

Of course, there have been many failures. In 2014, aware of the benefits of crop densification which allow manual labor, we tried to see how far we could move in this direction. Deliberately, we further tightened the already dense crops. It became clear that we had reached and passed the limit and because of that many crops were lost. But this experiment has given us reference points. **Crop intensification is valid up to a point, beyond that the results decrease.** In 2015, we returned to high density cultivation, which is more reasonable and the crops are generally more successful, with nice size vegetables; there was an impact on the economic performance. The results of the study reflect this trial and error essays.

The hotbeds

Inspired by reading the textbooks of the formerly Parisian gardeners and vegetable growers, we tried the hotbed cultivation. After a small trial in 2013, we set up many hotbeds in 2014 (10 beds from the 77 taken into consideration in the study), following the protocols of the nineteenth century in combination with contemporary approaches (precision seed drill ...). The results were interesting: the crops planted in early January

with a soil temperature of 20 ° C could offer an early harvest at the end of January (young sprouts). The summer crops that succeeded didn't receive heat, but benefited from higher soil fertility, matured earlier and were more productive. Late in the season, there was 15 to 20 cm of compost in place, which permanently transformed the small thickness of the initial substrate.

To create soil is for us a need and almost an obsession. The works of the nineteenth century show how our predecessors were driven by the same concern. We felt that our soil was being enriched and was gaining depth from year to year. The economic performance of this study doesn't mention this aggradation of the agroecosystem, yet real, as far as we can judge: the creation of humus, carbon sequestration, biodiversity... It is important to point out that **the high productivity of this approach is accompanied by an improvement of the environment.** Many hours of work were invested in the sustainability research. We place ourselves in a medium to long term perspective, and nevertheless, from the first years, the economic performance was encouraging.

The completion of this hotbeds trial took nearly 400 hours of work in the gardens, mainly due to the poor conception of our initial design. Based originally on animal traction, we didn't create a service road accessible to a medium-sized tractor for the gardens. The tractor of the equestrian club of Bec Hellouin, which offers manure, was obligated to discharge it on the entrance of the garden, so then we had to transport it with the wheelbarrow or the horse to the back of the greenhouse, under the deep muddy conditions of winter! If the manure would have been dump next to the location of hotbeds, the completion time would have been significantly lower. This experiment was carried out with the support of many trainees, which allowed us to invest these 400 hours in a few days (the working hours of trainees were obviously incorporated to Working Time). Within the framework of the study, this total number of hours was overrated by 50%, as well as all the other garden tasks. These nearly 600 hours dedicated to the hotbeds increased the workload in 2014 beyond the full-time equivalent. Almost all of the extra working hours that exceeded the full-time equivalent as consequence of the hotbed experiment, created the need to hire someone for several months, according to the calculation methods of the study. This is precisely discussed in the scientific report. This may contribute to misrepresent the data reading from the year of 2014, which is based on the evaluation of the potential remuneration: what for us was an experiment, had a considerable impact on the results. In our market garden economy (the good farmers count their money) we would not have invested as much time if we had to pay for each hour worked nor hired someone to set up the hotbeds! Ultimately, the total of hours decreased, returning to full-time equivalents at end of the study which correspondingly increased the potential remuneration.

This hotbed experiment has often been misunderstood to the point that we earned much criticism, sometimes surprisingly aggressive, coming from people who didn't take the trouble to visit us or ask us. To discredit the study, some have spread a rumor that the good results were related to the use of huge amounts of manure. Staggering figures have sometimes been invented….. We did not think that to try a technique of the nineteenth century allowing us to create soil and generate heat without a drop of oil would bring us so much criticism... Environmental movements are sometimes more violent than the society they denounce. The Internet gives everyone the power to disrespect people that he/she does not know and to hide behind the anonymity of his/her screen… At a time

when the arable land on the planet is disappearing at an accelerating rate, we hope that the importance of creating humus will be better seen: it is for your/our children that we work!

Pardon me for the digression and understand that what you are reading at this moment represent thousands of working hours freely shared with the farming community - one may not agree with our findings, but perhaps they deserve a minimum of kindness!

Until 2014, we did not import large quantities of fresh manure. In 2014, this manure was used almost exclusively on the hotbeds and for mulching walkways. Is it useful to clarify that we carefully ensured that this manure supply was well below the limit allowed by the European regulations for organic farming.

The farm, the place where solar energy is transformed

We learned the hard way (but there is a price to pay for every teaching!), a good network of access passages within the farm is a necessity. This point illustrates the importance of an excellent design for the performance of the farm. **We can save ourselves a lot of work through optimal design.** For example, short unnecessary repeated trips every day between the studio and the gardens eventually represent several hours lost each week, and this results in fatigue and costs - higher costs because the workforce is paid. Another limitation of our farm: The gardens are located south of the river, while the shop, where the crops are packaged and shipped is located about 200 meters away at the entrance of the farm. All crops throughout the year, no matter the weather, are transported with the wheelbarrow to the shop which is located on top of a hill... And it takes dozens of wheelbarrows to fill a vegetable truck! Useless efforts, as hidden costs that could have been avoided if this had been considered ahead! The potential compensation calculated in the scientific report reflects these design flaws that increase the result to hundreds of hours. These teachings deserve to be pondered... There are solutions: I made a “wheelbarrow workshop” containing almost everything I need to work which prevents me from coming back multiple times a day to the greenhouse workshop. In 2015, we finally built a dirt road that connects the center of the gardens to the rest of the farm. It just took us ten years to make this decision, because of the cost of the road ... miscalculation!

The more we think about these issues, the more it appears to us that the **farm is a "power plant" designed to transform the sun, thanks in part to photosynthesis, in an "edible landscape" that will meet the nutritional needs of humans, while providing many other functions serving the entire biosphere.** The effectiveness of this process of transformation and storage of solar energy in soils, trees, ponds, cultivated plants, the human and animal bodies, depends on various factors: relevance of design, the efficiency of farming practices, spare of efforts through the use of effective tools and good organization. **When we work by hand, we transform the solar energy stored in plants and animals that feed us in the form of workforce.** Each path that can be avoided, every useless gesture, each task that needs to be repeated twice because of poor organization, each heavy tool, each wheelbarrow unnecessarily pushed, represents in this

perspective a waste of energy which translates into a lower economic efficiency for the farm... We must fight against entropy. Laziness is sometimes a good counselor!

To think about the energy flows within the farm helps to have a better perception of its effectiveness. The working hours reflect the amount of energy spend to get a harvest. The money resulting from the sale of this crop is also a form of energy. For example, by reducing the weight of a tool with a lighter handle (hoeing requires the repetition of thousands of gestures per hour, sparing few grams on each gesture would translate into hundreds of kilos at the end of the day) or by creating a tool that would help achieve a task better and faster (like the Campagnole), we save hours of work, which translates into better remuneration or free time that can be devoted to the family … Caught in a project continually delayed by the daily rush, we do not always give the necessary hindsight to this awareness that can lead to improved efficiency, and therefore, a better chance for the project's survival.

But a design is never achieved, it is always evolving - who can claim to consider all the constraints, all future options, during the initial attainment? Therefore, the efficiency of the farm also depends on our ability to perceive the signals, the feedback loops, and our creativity to develop, every time, appropriate responses.

Fertility

Over the years, especially as a result of the exchanges with many researchers, technicians and practitioners, we better understand the fertility cycle. We are seeking a self-fertility farm and have many resources of plant and animal origin within it. The permaculture design of the farm allows us to loop the cycles. We observe and intensify the possible connections between our gardens, fruit trees, ponds, hedges, paths, forest, small breeding area, a habitat and plant cultivation for biomass... All these elements are present in our cultivated plots, and come to support the fertility and sustainability.

The external inputs are not neglected and our strategy is relatively opportunistic: always concern in creating soil and increase the organic matter content of our gardens (this is a way to store carbon and ensure to leave a fertile soil for future generations), when someone offers us a manure trailer or BRF (ramial chipped wood) we do not refuse it! This helps to loop the cycles at the scale of the territory and illustrates a principle of permaculture: any waste from an activity that is not recycled within a system becomes a pollutant outside of it; what is garbage for some must become a resource for the others.

The valorization of multiple sources of organic materials from inside or outside the farm has freed us from the need to buy fertilizer. Over the last 10 years of market gardening, we have only purchased organic fertilizer during three years (2010 to 2013) and have no need today.

Marketing

The geographical location of the farm, out in the country, far from urban centers, in the heart of a region where organic farming only represents 1% of the SAU (Utilized Agricultural Area) does not promote the commercialization of our products. Honestly, we must add that we are more interested in the quest of natural agriculture than placing ourselves on the market of fruits, berries, vegetables, edible flowers, aromatic plants and processed products that leave from the farm. The commercialization is still our weak point.

Part of the production is sold at the farm shop on a weekly basis in the form of vegetable baskets, but this direct sale represents only a few dozen baskets per week, despite our efforts.

Another part of the production is consumed by the team and the family but especially in the eco-center during the workshops (trainees, trainers, and the permanent employees could form a team of fifty people!).

Other products go to the wholesalers: aromatic plants, for example, go to our friend Benjamin Decooster of ALTERNOO who sells them to retail chains or restaurants. So there are two intermediaries between the consumer and our farm.

Recently we began to sell to the Biocoop Greendy et Dada, with whom we have a relationship of trust.

We also supply our products to a wholesaler specialized in a premium segment.

We supply directly to a few restaurants, most of them gourmet.

Finally, we have a chef working full time on the farm that produces various processed products sold in the farm shop (high demand). We are proud to work for some of the best restaurants in France. The requirements of the top chefs, who are actively seeking our products and verify the taste quality of our fruits and vegetables, grown in an extremely natural way, pushes us to constantly to progress. The fact that some market gardeners come from the world of catering have helped us to develop an in-house expertise in this segment. Our vegetable basket's customers benefit from this research.

From the wholesaler to the multi-starred chef via direct sales, we are experimenting extremely diversified markets, which constitute a heavy burden on the team in terms of management and organization.

Our dream to feed the school canteen of our children has not yet been made.

During the research program, our project was never aimed to produce, either exclusively or principally AMAP vegetable baskets. If that would have been our objective, we would have done things differently, for example by including more field vegetables (we would have sought ways to intensify their cultivation, for example, attaching the squash, which work well). The working time would have probably been lower as well as the GS. We believe that it is quite possible to produce balanced vegetable baskets all year long on a small area; we did it for us in the past. From this perspective, the purchase of semi-perishable vegetables may be occasionally needed during winter time to complete the production. However, it would probably be wise to cultivate, for example, 500 m^2 approx. of very diverse vegetables (in Zone 1, according to the permaculture principles) and an additional 1,000 m^2 of semi - perishable vegetables, a system that requires less work than the permanent raised beds (in Zone 2). The working time would not necessarily be very different from that of the study.

Note, that during the study, we developed a partnership with an ambitious project in Paris; the progressive opening of their restaurants absorbed an increasing share of our production. However, this project brutally collapsed in autumn 2014, we lost in one week most of our markets. It took us months to recover. Many established crops were not harvested between September 2014 and March 2015 (the closing date of the study). This explains the decline in the economic performance at the end of the study while the gardens were particularly well filled with crops.

The farm covers over 1,000 m^2!

Another aspect of the study which is sometimes misinterpreted is that some people thought that we advocate farms of only 1,000 m^2 (we should remmeber that within the framework of the study, we studied 1,000 m^2 cultivated, to which should be added the walkways, the buildings and the rest of the farm). That is not our objective. Certainly in cities, where land is scarce and expensive, the very intensive approach developed at Bec Hellouin Farm can allow to make the most of all small spaces. However, in rural areas, **it seems important to consider the farm as a whole, to visualize it as a whole in which each element performs many functions**, as proposed in permaculture. Depending on the context and objectives, the farm can vary in size. Our farm size is 20 hectares, including 12 hectares of wood, 4,000 to 7,000 m^2 of vegetable crops depending on the year, the rest is pre-orchard and forest garden.

The scientific report highlights the fact that the marketed production from 1,000 m^2 cultivated ensures an income equivalent to other forms of diversified organic market gardening, but on a much smaller surface area. This is particularly interesting and deserves to be developed: **if 1,000 m^2 cultivated allow ensuring a vegetable production of a full-time equivalent, we freed 9,000 m^2 for other uses, with nearly the same production:** plant fruit trees (it is the trees that will save the planet, not annual crops! They can cover 80% of the micro-farm, planted as edible hedgerows, forest-garden, meadow-orchard, and vegetable-orchard), raise animals, build an eco-housing, dig ponds, install hives, etc.

A permaculture micro-farm of one hectare can therefore provide vegetables, but also many other agricultural products and provide work for more than one person,

while being a real diverse agro-ecosystem that produces the necessary biomass to maintain the fertility of the vegetable plot. So we have a more self-fertile and resilient environment. And the more time passes, the more it gains independence. This is verified each day at Bec Hellouin.

The Interest of making the different systems coexist

As mentioned in the scientific report the 1,000 m² gardens studied as part of the program, constitute an area generally well maintained (Zone 1), according to permaculture – such was at least our initial plan. However, the more the study progressed the more we saw, that in our approach, these 1,000 m² were still too big and that we couldn't maintain effectively each plot (for this reason the mandala was very neglected, and becoming in effect a "Zone 2"). However**, we cannot overemphasize enough, that the intensity of the maintenance is absolutely crucial for the success of this form of gardening based on manual labor.** We therefore think that for a full-time equivalent, whose goal is to cultivate a wide range of vegetables, a smaller surface area would be more appropriate. There is much interest to intensively maintain small spaces (however, to a certain degree of intensification as highlighted in the scientific report). In our perspective being small is an advantage as was already stated by the Parisian gardeners and vegetable growers in 1845th!

We must understand the essential difference between a mechanized approach of organic gardening and our approach based on manual labor. When one has a tractor, it only takes a few hours to prepare the soil of an additional field of half a hectare. Manually, that extra 100 m² would represent a great hassle....

At Bec, we see that **each cropping system has its advantages and disadvantages: it may be interesting to make the different approaches coexist.**

We do not believe that the permanent raised bed cultivation is a panacea, even though there are many benefits to this approach. We have different types and forms of raised beds as discussed before: mounded raised beds, flat beds (Coleman) and large mounded raised beds that are covered and used for perennial crops (rhubarb, artichoke ...).

Alongside the 1,000 m² studied, we always kept gardens using **animal traction for open field vegetables** like squash, potato, turnip, carrot, etc. We even made significant progress in animal traction during the study (thanks to the harrow weeder and the intercrops grown on flatten ridges). The time invested per unit area is considerably less than for the permanent raised beds and the results are interesting.

But the great advantage of the raised beds is that we can cultivate them all year long, whereas, to offset the loss of fertility caused by the use of animal traction, we succeed cover crops with vegetable crops. **The number of rotations performed on the permanent raised beds is always more important (up to 8) than in the gardens with animal traction**.

The study has not really examined this aspect, **but all our gardens are carried out practicing agroforestry (vegetable-orchards)**. The Bec Hellouin Farm is participating in another research program underway dedicated to vegetable-orchards, CASDAR SMART program.

The tools

Working entirely by hand or with a horse, while minimizing the use of fossil fuels is not part of our profession as arborists and market gardeners is like returning to the past. One day, we won't have oil or it will be unaffordable. **Given the impact of agriculture on global warming, seeking to avoid whenever possible, the use of combustion engines and soil tillage is an ethical posture rather than agronomic choice.**

This constraint we impose upon ourselves proved to be liberating. We are focused on the research of suitable tools for a micro-agriculture based on manual labor, following three paths: studying the tools dating before mechanization, taking a look at the contemporary suitable tools and developing new ones. During the last few years, we had pleasant surprises. The most wonderful one is the creation of the Campagnole in partnership with Vincent Legris from the Fabriculture, a hand tool that allows preparing quickly and very efficiently the permanent flat beds. The Campagnole demonstrate that a manual tool can advantageously replace a heat engine, with investment and functioning costs incomparably lower while preserving the soil. Those who wish to know more will find a report on the tools on our website: http://www.fermedubec.com/outils.aspx. Fabriculture has been commercializing the Campagnole since recent months.

At the beginning of the study, we occasionally use a rototiller to save time in the preparation of the beds. The use of the broadfork was labor intensive and slow, especially because it lifts up clumps of soil which then have to be broken up; this tends to spoil the mounded raised bed which latter needs to be reshaped with the rake. However, during the last year of the study, the rototiller was never used. The Campagnole allows us to quickly decompact our flat beds (its width is 80 cm, as the bed) and if we compare it with the broadfork and the rototiller the gain in time and efforts is substantial. This inexpensive tool frees us from the use of fossil fuels, with no maintenance costs it allows us to reconcile the garden priorities (deep and light soil), and those of the soil (the soil is not abused or turned around). Moreover, the more we mulch our flat beds, the less the soil is likely to compact.

The method of the Bec Hellouin Farm

By reading the preceding lines we notice that the study was not performed in an "ideal" environment, but within a real farm, constantly destabilized by the media coverage and excessive demands, subjected to additional commercial risks. The results of the study do not constitute a "record" made by a few gifted in an optimal context, such as the athletes' records. To the contrary, with François and the Scientific Committee, we have constantly sought that the results reflect the "normal" functioning of a farm, therefore, the average results. For this reason, the potential compensation was calculated only for the first two calendar years of the study. This should be somehow reassuring for our colleagues.

We are very aware of the limitations of our farm. It was conceived over the years without a real initial overall design. Each year we seek to rectify this lack of overall conception. For example, we don't have a washing station or a cold room. In addition, as mentioned before, we didn't have until this study any point of reference in order to effectively scale the size of gardens. If we were to do it again with the experience gained

throughout, the farm would certainly be very different! The advice given in our training courses comes just as much from our mistakes as from our successes.

To the best of my knowledge, we can only certify that the farm team now enjoys a unique experience in this type of bio-inspired agriculture, an experience that has been nourished not only by our ten-year research and the study but also from the experts' opinions who visited us, not to mention the thousands of trainees, often very competent, that we hosted as part of our training courses. About fifteen collaborators, permanent or regular were working on the farm around these issues. Some trainees carry out at the farm their final theses. Various scientific and technical institutes are accompanying us. Let this experience serve others!

A possible challenge while developing a type of agriculture that contrasts quite sharply with earlier approaches, is to give it an overall coherence and to ensure its economic and ecological relevance. This requires taking into consideration many parameters such as agronomic, environmental and human. How can we unite all these concerns in a coherent approach and achieve a maximum effect with a large economy of energy and technological means?

For many years, we have practiced this approach and have described it as The Method of the Bec Hellouin Farm.

Let us be clear: this method is named after our farm because it was created there. We have no desire for hegemony. There is no intention to duplicate our farm in other territories: It would be against the spirit of permaculture, which wants that every project would adapt best to its environmental and societal context as well as to the aspirations of the project leaders.

This method, which is available on our website, does not provide specific technical guidance. Rather, it aims to provide conceptual references that can help those who wish to create a bio-inspired system. We believe that this approach may enable others to avoid disappointment and save time and money.

If you want to know more go to:

http://www.ecoledepermaculture.org/images/methode%20de%20la%20Ferme%20du%20Bec%20Hellouin.pdf

The rise of micro-farms

We have chosen to host media requests and to open up the farm to diverse audiences, particularly within the framework of the training courses, some of which are specifically dedicated to professional gardeners, because we feel, as we stated before, we have the duty to share this approach. The media allows new ideas to spread quickly. Each national broadcast about the farm allows hundreds of thousands of people to discover innovative concepts but as a result of this, we carry with the responsibility to answer, in addition to our daily work, to hundreds of calls and emails! At a time when so many threats are facing the planet, can we keep to ourselves potential solutions?

We must recognize that this choice of opening up to the media has not only given us friends, but has led to a great movement (of which we were the first to be surprised)

within the profession and the institutions of the civil society both in France and abroad. Each day a growing number of initiatives inspired by permaculture and the concept of permacultural micro-farming are spreading like wildfire. Farms are being created, and thousands more, without exaggeration, are in the process of being created.

The agricultural support structures have found themselves surprised and often powerless to accompany atypical requests from project leaders. Permacultural micro-agriculture goes beyond the traditional reference points and criteria, particularly in terms of the land, the access to an agricultural status and the technical processes. New answers need to be found and support strategies should be imagined. We are in touch with various organizations and work together on these issues. At the request of the Ministry of Agriculture, for example, we sometimes organize sessions for trainers in agricultural education. We also host city officials from different cities of European capitals wishing to implement such forms of micro-farming on their territory in order to increase their food security. Sometimes we are invited to different institutions to present the Bec Hellouin experience, institutions like the European Parliament and the Economic Social and Environmental Council, a sign that these institutions are opening up to new paradigms. The imperative need to fight against climate change creates an emerging interest for this form of agriculture which stores carbon in soils and trees; we hope that when the farmers adopt this model, they start to benefit from new forms of support under the carbon offset program which is already the case for Bec Hellouin for planting fruit trees.

A number of project leaders are motivated by a deep desire to reconnect with nature and sometimes are blurred by a certain naivety and by an idealized image of the rural life. We perfectly understand them; our approach was at first idealistic and naive. Fortunately it remained strong: What could be worse than falling into a strictly utilitarian approach! **We cannot stress enough how living from organic gardening is a full-time job profession, which is one of the most complex and demanding**. No profession can be learned in a few months. A good preparation is essential**. We must devote, if it is not out field, several years: it is time, effort and investments gained for the future**. Unfortunately, there is not a training program for those wishing to adopt a model of permacultural micro-farm (apart from the specific nature of the permaculture biointensive approach that Bec Hellouin Farm is developing as a complement to the BPREA (Professional Diploma in Agricultural Operations Management). We got close to our friends of the Sainte Marthe Farm and together we are offering training). Our techniques have hardly been described in detail so far. We are aware of this gap and intend to narrow it: we have helped to create a "desire" for knowledge but we haven't had the time to describe precisely from a technical point of view the solutions we are implementing [11].

We would emphasize that the good economic performance achieved in the study is not only related to permaculture. Permaculture is fundamental to our approach because it

[11] It is clear that a number of project leaders venture down this path without sufficient technical background. For this reason, in 2016, we will welcome visitors at the Bec Hellouin farm, only on certain days, in order to make more time available for the necessary technical support describing the micro-market gardening practiced at the farm, this is a project that has been continually delayed due to the everyday rush. Forgive us for our unavailability. Despite the efforts of the whole team, we struggle to respond to every email and phone call, we are trying to work on the key issues that will benefit the community.

provides a simple and effective conceptual framework, enabling the design of a farm that functions as much as possible like a natural ecosystem. Permaculture can inspire extremely diverse achievements and that's fine but it should be remembered that permaculture is not a set of agricultural techniques. At Bec Hellouin, we implemented the design concepts of permaculture, but we have also gathered and assembled many biointensive techniques, and developed practical and specific tools that allowed us to achieve the economic performance presented herein. Without these techniques, Permaculture alone does not allow to obtain as far as we can tell such results.

In other words, it is not enough to be trained in permaculture (even with a good training) to be able to create a micro-farm. We cannot overemphasize the fact that to succeed in this challenging adventure, it is appropriate, in our view, to be trained in organic market gardening, organic arboriculture and other production areas that we wish to exercise (breeding, processing, WFP ...) according to the classic approach. When one masters the basic practices, one can add the permacultural or biointensive characteristics taking inspiration from the Bec Hellouin method if desired, or developing its own approach… Obviously this is not what we have done, instead our learning has been erratic and if we had done it in a different way we could have saved time and effort!

In other words, permaculture is a conceptual system above all, and in no way, replaces the technical knowledge essential to achieve a sustainable production level, however, it brings to these techniques an additional dimension that allows imagining a bio-inspired system that constantly seeks to enhance the ecosystem services, which is not always the case for farmers even when they are organic.

Could permaculture provide a boost to organic farming and give it a greater coherence allowing it to further integrate key contemporary environmental issues (climate, soil, water and biodiversity protection), at a time when industrialization becomes a strong trend?

Support to the project leaders

The permacultural micro–farms are adaptable to innumerable contexts and could eventually link the entire territory, meeting the needs of local communities. In Europe, there are potentially millions of people to be trained in the coming years. The needs and challenges are immense. It seems necessary to work on several fronts:

- Develop the scientific research and technical and economic studies (this first study has been a catalyst for research programs in various places and countries).
- Training of trainers and practitioners capable of transmitting their knowledge.
- Propose appropriate training.
- Create teaching tools.
- Support the creation of learning centers (farms, training centers and specialized branches within institutions...).
- Enable specific support measures (tailored loans, solidarity mechanisms, installation aids, carbon credits...).

We are working on all of these fronts, with all our means, together with various partners. We feel that the movement is growing and that more and more people are committed towards a bio-inspired agriculture or aspire to do so. But it takes time (several

years) to train people and to create learning centers, chances are that we will still go through some rough years, with a blossoming of initiatives more or less prepared, which are going to contribute to gradually explore new cognitive territories. We invite the adventurous candidates to exercise restraint and humility, and in particular not to call themselves “experts on gardening" or "trainers" before actually having experienced the profession and acquired a credible field experience. Being in a position to support the project leaders is a responsibility that should not be taken lightly: every failure, which there are, can lead to a spoil dream, a ruined family, the end of a relationship … Everyone should exercise discretion and prudence... without forgetting the necessary dose of audacity to approach this *terra incognita* that bio-inspired agriculture represents! Be pragmatic dreamers!

At Bec Hellouin, we have written a book[12] that details the proposals quickly outlined in these lines and deepen the essential concepts. We have made four educational films on permacultural agriculture[13]. We are in the process of making more practical films. We also brought together many resources on our documentary Database[14]. A big practical 500-page manual is in the process of writing, it will contain different conceptual and technical information which is not often available today. Its publication is scheduled for spring 2017.

The main lessons of the study

After having discussed on a regular base with those who conducted the study (scientists, engineers, and gardeners) they are quite willing to agree that the figures say both much and little.

Much, as the study demonstrates the amazing potential of a bio-inspired micro-agriculture based on manual labor. These are the first steps. Therefore, it is relevant to explore this further!

Much, because the data have set up the essential points of reference, especially those we were lacking at the beginning! For the market gardeners that are tempted to engage in this approach. We can identify the main ones based on data from the last 12 months of the study (1,600 hours of work in the gardens have generated a marketed production of 54,600 €):

- **It takes about 1.6 hours per year to intensively cultivate one square meter of permanent raised bed,** according to our method (more for a beginner and lees for someone with experience).
- **Each square meter can produce a value of about 55 €,** in a similar context to the Bec Hellouin (with experience).
- **Each hour of work in the gardens produces a turnover of about 34 €.**
- - In addition to the hours worked in the gardens 50% of extra time dedicated to other tasks; **each hour worked generates a turnover of about 23€.**

[12] « Permaculture – Healing the Earth, feeding the people » Perrine and Charles HERVE-GRUYER, Actes Sud 2014.
[13] http://www.ecoledepermaculture.org/films-et-livres.html
[14] http://www.ecoledepermaculture.org/accueil.html

- **The cost of all the tools used to achieve this production (greenhouses, irrigation, various tools) is about 22,000 €[15].**
- A person can effectively take care of an area of between 500 and 1,000 m^2.
- With equal labor intensity, the more the surface is reduced, the faster the value created increases (up to a certain limit).

These simple data can show the difference between a blind progress and be able to conceive the cropping system in a more realistic manner.

However, it is better to consider these indications as points of reference, rather than taking them literally**. A number of parameters influence these results: Are you fast or slow? Is your soil fertile or barren? Are you very organized or messy? Are you located far from your customers or on their doorstep? Do you have good business skills? Direct sale or through a wholesaler? According to the responses to these questions your result may be much lower or better than ours.**

We found that the production of our gardens have increased significantly and rapidly year by year. This trend continues significantly from the rest after the cessation of the study. The reasons are clearly presented in the scientific report. At the end of the study, the productivity of certain plots surprised us. And we see many opportunities to improve our practices!

Ultimately, this first study represents the "kindergarten" level of bio-inspired agriculture: the margin of progress remains very important! If the research effort intensifies and the means would be available to scientists, practitioners, and trainers, there is no doubt that we will go far and fast together.

Potential remuneration

The scientific report presents potential revenue hypotheses for the first two calendar years of the study. The data were processed as objectively as possible so as to provide reliable indications. We saw how the total number of hours dedicated to the hotbeds was integrated into the 2014 results, even though these had been performed by trainees.

During the last months of the study, the number of hours worked in the gardens returned to a full-time equivalent (a very large full-time equivalent if we integrate the 50% of the time that is dedicated to related tasks) especially because we didn't repeat the hotbed's experiment (we are making small ones for plant production). The economic results reflect the fertility contribution resulting from last year's work.

The data reading of the last months of the study suggests the possibility of a potentially higher compensation; however, the calculation was not performed because we didn't have a full calendar year.

Note also that these results are obtained without taking into account any subsidy (ADI tax credit AB). If the micro-farm is interested in a subsidy and is able to obtain it, the ADI

[15] This data is extracted from the master's thesis 2 of Morgane Goirand at AgroParisTech.

covers roughly the cost of equipment and tools which can help reduce the investments. This was not our case.

Another element in favor of the high potential of this type of practice is the difference in productivity of the beds. During the last 12 months of the study the production of several beds in the greenhouse exceeded 200 € per square meter, but the others, particularly in the mandala produced less than 2 € per square meter (unharvested aromatic plants or failed crops)! This confirms that it is better to work on a small area, well maintain, rather than to spread the workforce over a large area.

We believe that an experienced market gardener, that cultivates on fertile soil, with a good sales network, can reach a higher remuneration than those calculated in the framework of the first two years of the study. However, it is important to temper this statement by the fact that the very conception of a permacultural micro-farm (which is a complex and diversified agricultural system) makes it "high demanding" in terms of maintenance... **A certain number of working hours will not be dedicated to gardening, but maintaining trees, Berries, animals... these can potentially be a source of income, if there are valued. It is obvious that managing a permacultural micro-farm is different from a traditional market farm. We must recognize that there is not, to date, accounting data on the overall economy of this type of farm.** Obtaining these data would probably be impossible as the configurations can be different from one farm to another. The farmer who wishes to set up this system must exercise common sense. If he does not have enough starting capital, it will be advantageous to focus initially on the vegetable crops that would, in the short-term, be most profitable, and only afterwards to look after the rest of the territory as the resources will allow it (planting trees, hedges, digging a pond, etc.).

One might add to the above that a permacultural micro-farm produces much more than food: it performs many environmental and societal functions, as we shall see. Some of these functions are so necessary that they would justify specific support devices.

A permacultural micro-farm is an innovative system, not very know, very attractive, as we have mentioned it before and can also (must?) become a training center. The hosting of trainees as part of BPREA or the organization of collective projects (for example planting of orchards...) can eventually reduce the workload of the farmers. But one should not underestimate the time and energy of hosting trainees if we agree to make ourselves available so that their stay at the farm is really educative...

The issue of potential compensation is complex and dependent on many parameters. From our perspective, it is difficult to give precise figures for reference; however, our experience leads us to think that it can be substantially equivalent or superior to that obtained through a conventional operation.

Is this type of practice difficult to implement?

Is it more difficult to practice the fine art of organic market gardening based on this approach rather than using mechanization? In a sense, the path of Bec Hellouin proposes a true simplification: hand tools are user-friendly as defined by Ivan Illich! But it demands

certain knowledge of nature, more observation, more "eyes per acre" according to the words of Wes Jackson, one of the pioneers of bio-inspired agriculture in the US.

It is also undeniable that **the crop intensification is a challenge for the market gardener:** intercropping, densification, relay crops which require precise management, and weather data can affect the results (for example, during wet weather conditions there is more risk of rot when the crops are planted too close together). The experience of the market gardener matters a lot.

A new agriculture

At a time when the farmland artificialization generalizes**, this bio-inspired approach proposes to deliberately make the farm more complex.** In order to restore an agroecosystem, it is necessary to make it a little more complex every year, mimicking nature. **The farmer must take a different approach: he/she should agree not to control everything, have trust, observe a lot, know not to intervene, use his/her reason but also give way to intuition –** because intuition often proves to be better at understanding the highly complex systems...

The time relationship also changes: we do not necessarily aim for maximum productivity in each harvest but the sustainability of the agroecosystem. Numerous working hours are invested in tasks which are not immediately profitable (create the soil, plant a hedge, a forest garden, dig a pond), but will eventually contribute to enhancement of the ecosystem services. **Even a small contribution to the health of the biosphere is in our perspective more meaningful than a large turnover.** Would the soil that we will leave to our children be more fertile than the one we found at the beginning of the installation of the project? The good news is that in this approach, nature offers us beautiful and sustainable harvests! We take care of the earth; the earth takes care of us.

Another aspect of this permacultural agriculture is its high "human density": the farm is more than a workplace; it is also a living space, often invested with a strong affective charge. Perhaps is an innovative practice that breaks certain codes of mainstream society (that has given priority to material stuff, short-term profit, competition) and that responds to the ethics of permaculture [16], in search of new paradigms. In this sense, it attracts and brings people together creating social links. It invites us to imagine new settling methods that are often collective, new forms of governance... None of this is simple, and yet we must respond to these key challenges!

Ultimately, this new agriculture also refers to our internal ecology and raises the question about our values, the meaning that we give to our lives, the idea that we have of happiness and our relationship to ourselves to others and nature.

An open gap in our collective imagination

Over the years, we have become aware that **the *economic viability* of the farm depends on its *ecological sustainability***. In other words, when the agroecosystem is

[16] Care for the Earth; Care for People; Faire share.

gaining in maturity and diversity the ecosystem services increase, the organic material is increasingly available, the soil gets richer, beneficial organisms are present and effective, and the farmer is rewarded with bountiful harvests, with a decreasing workload the farm is gaining autonomy and resilience, the time is in our favor, we are part of a true sustainability. We begin, in a way, an upward spiral. At the beginning it takes a lot of effort to initiate the movement, but as the agroecosystem unfolds the efforts diminish.

When the farmer restores his farm with awareness and discernment he gains in productivity. The latter is not related to large amounts of fossil fuels or inputs, but the valuation of the free services that nature offers us.

The dominant thinking in agriculture generally perceives the need to protect the environment as an obstacle to productivity. This reflects the fact that since the Neolithic, our western agriculture has consistently simplified and artificialized spontaneous ecosystems. This study proposes an exactly opposite view: **We seek to imitate the spontaneous ecosystems because nature is supremely productive and sustainable. It is by observing it and being inspired by it, that our farms would also become productive and sustainable**. **In other words, it is possible to combine environmental improvement and the growth of human activities** in our field, based on the value of biological resources.

The positive externalities

The figures from the study show that this gardening approach based on manual labor proves to be relevant from an economic point of view. But it is also relevant for nature and society, so much that **the positive externalities are numerous and important**. We could not, at this stage, demonstrate them scientifically; the following will be the subject of future work:

Main environmental externalities:

- Creation of humus.
- Carbon sequestration in soils.
- Carbon sequestration in trees.
- Improvement of biodiversity.
- Creation of favorable microclimates.
- Water protection (ponds, rivers, groundwater).
- Etc.

Main social externalities:

- Job creation.
- Relocation of the food production.
- Less use of fossil fuels.
- Local production of quality organic foods: health impact.
- Social bond.
- Beautification of landscapes.
- Etc.

The second research program, which started in 2015 at Bec Hellouin, will focus among other things to assess the carbon sequestration (therefore, the contribution to the fight against global warming), and the impact of this type of agriculture on the biodiversity - two key challenges for our common future.

In conclusion, perhaps this study goes well beyond its original purpose: it leads to imagining a new form of agriculture that would concentrate a large part of food production on small areas intensively maintained and would free up vast areas that could be planted with edible forests or returned to their wild nature. It would then be possible to conciliate in a sustainable manner the needs of humans and those of the planet. But that's another story!

For the farm team,

Charles HERVE-GRUYER

Bec Hellouin, November 19, 2015.

Acknowledgments

Although the task was hard, I want to express my immense gratitude to all who have made this adventure possible, which proved to be from the beginning to the end deeply respectful and pleasant:

François Léger, who had the audacity to commit his institution to a research program on marginal agriculture and navigated the ship with discernment.

Yohann Jourdan, Jean-Claude Bellencontre, Thomas Henriot, Teddy Perez, Jean-Pierre Bellencontre, the brave market gardeners who took note of the study data and the trainees who have effectively supported them.

Sacha Guégan, the engineer who processed and analyzed the data, a real painstaking task, without having lost his sense of humor!

Edith Legay, Fabien Prudhomme, the farm team that created a favorable context for the study with skill and good humor, so that the work could be achieved in the best conditions.

Kevin Morel, who performed within the framework of his Doctorate a thorough work on micro – farms, as well as the students of the master's 2 degree of Agronomy who have performed their final year internship at the farm and made brilliant contributions: Morgane Goirand, Alexis de Lidekercke, Clara Carrayrou and Eskani Siruguet.

The members of the Scientific Committee:

Christine Aubry, UMR SAD-APT Paris, INRA SAD, Agronomy

Stéphane Bellon, UR ECODEVELOPMENT AVIGNON, INRA SAD, AGROECOLOGY

Gauthier Chapelle, Biomimts, GREENLOOP

Nathalie Corroyer, Chamber of Agriculture of Normandy

Philippe Desbrosses Sainte Marthe Farm, Agronomy

Marc Dufumier, UFR Comparative Agriculture and Agricultural Development, AgroParisTech

Pablo Servigne, Researcher, Writer

Pierre Stassart, University of Liège, Sociology

Serge Valet, Agronomist

Nicolas Vereecken, Agroecology, Free University of Bruxelles, Landscape Ecology & Plant Production Systems.

Members of the Board of Directors of the Sylva Institute:

Philippe Desbrosses, Lucile De Cossé Brissac, Sébastien Henry, Fréderic Proniewski, Louis-Albert De Broglie, Laurent De Chérisay, François Lemarchand, Alexandre Poussin.

Our partners, who often became valuable friends and the institutions they represent:

Lemarchand Foundation for the Balance between Mankind and the Earth

Fondation Léa Nature

Terra symbiosis Foundation

Pierre Rabhi Foundation

Fondation Picard

Charlotte de Mévius

Nicolas and Marina Plowiecki - BALT

The Ivory Foundation

And all the people who surrounded us for their encouragement and sympathy, too numerous to mention everyone here!

We wish from the heart much success and happiness to those who are committed to a better planet!