Diversity of Innovation Processes in the Niayes Market Gardening System (Senegal): Between Conventional Intensification and Agro-Ecological Transition

Development of the vegetable sector in Senegal has been based on technical innovations such as motor pumping, use of inputs, net-shades, etc. A survey of 22 market gardeners in Southern Senegal in the Niayes has highlighted the diversity of innovation processes and related factors that drive it. Exchanges between vegetable exporters and market gardeners in a same area have enabled the adoption of localized (drip) irrigation. The use of natural inputs (biopesticides, repellents, organic fertilizers) answers to an “agro-ecological” specification and is promoted by NGOs. Ultimately, different vegetable crop combinations have been designed and adopted by innovative gardeners to address the reduction of surface area, although these have not yet been “disseminated”. These examples highlight the capacities of West African farmers to innovate and adapt. They question the type of methods and tools needing to be developed in order to accompany these processes without limiting the creativity of farmers or the flexibility and performance of local innovation systems that they create.

6.1. Introduction

Market gardening is one of the most dynamic agricultural production sectors in sub-Saharan Africa, despite being very poorly connected to global markets. Production systems in this sector have changed rapidly over the last 30 years due to the rapid increase in demand for vegetables from urban

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residents, of which the number has risen sharply (Figure 6.1). For our analysis, we selected two crops that have been widely adopted by consumers over the past 30 years, corn and tomato, in addition to a traditional food grain, millet. According to FAO statistics, corn production more than doubled (times 2.2) between 1990 and 2014, and its recent increase is also due to it being used for livestock feed production following the development of short cycle animal husbandry. Tomato production has increased fourfold and is almost entirely destined for fresh sale with very little processing and no export outside the area concerned. Finally, millet production has recently declined as consumers (mainly urban) have turned away from this food grain as it takes a long time to prepare.

Burkina Faso’s Ministry of Agriculture, Hydraulics and Fishery Resources (2007) highlighted the growing importance of market gardening in the country through an increase in professional market gardeners from 70,000 to 96,000 between 1996 and 2001. The cultivated surface area also increased by 7% during the same period despite the difficulties accessing irrigation water in this country. All West African Sahelian countries were involved in this development, Senegal first and foremost because production conditions are more favorable in the Sahel than in humid forest zones. Sahelian market gardeners produce crops for their own countries but they also export to larger markets further South (Abidjan, Accra, etc.).

**Figure 6.1. Evolution of tomato production and some cereals in West Africa** (source: FAOStat). For a color version of this figure, see www.iste.co.uk/temple/innovation.zip
The most notable changes have been in production, while vegetable marketing, preservation and processing practices have changed relatively little. Market gardeners widely adopted improved seeds, especially for tomatoes, cabbages and onions, which were produced by specialized companies, and also chemical inputs (fertilizers and pesticides). More recently, a minority of market gardeners have been equipped with motor pumps and localized or drip irrigation [VEN 14]. These innovations are part of a process of production intensification arising from the Green Revolution, which started in the 1960s [DUG 12]. This intensification, which is now described as “conventional”, has led to an increase in the quantities produced due to reduced pest pressure, the development of mineral fertilization and nearly year-round production.

Nowadays, this conventional process of intensification is called into question by research [DE 14] and civil society [CIS 06], in view of the potential impacts of market gardening systems on the environment and the health of both producers and consumers. This has led to the emergence of stakeholder groups that promote sustainable agriculture, agro-ecological practices and effective consideration of the environmental impacts of current forms of agriculture or research recommendations. In sub-Saharan Africa, market gardening is often put on the spot because (1) it uses higher doses of pesticides than other annual crops (cereals, legumes, etc.) and perennial crops (mango trees, citrus fruits, etc.) and (2) pesticide residues are found in consumed vegetables, soils and groundwater [NGO 12, DIO 14].

The aim of this chapter is to analyze some recent innovation processes in the market gardening sector and to assess their exogenous and endogenous determinants. This study is part of a research and development initiative led by the Center for International Cooperation in Agricultural Research for Development (CIRAD), which focuses on the agro-ecological transition of market gardening systems in West Africa.

6.2. Theoretical position

The term “innovation” refers here to the technical, economic and social process of change as carried out by a farmer and based on inventions. Inventions or discoveries (in our case, drip irrigation, biopesticides or a new marketing strategy) can be created by a farmer, a producer organization, a researcher or an engineer within a company. Innovation is therefore defined as a new way of doing and organizing [SIB 07] and refers to a new
technical or managerial practice, or a new combination of practices [DUG 06, BLA 13]. Therefore, the innovation process is the farmer’s (and not the inventor’s) responsibility. This process goes beyond the simple implementation or adoption of a technique. Much of the literature on innovation theory has focused on the ability of entrepreneurs and consumers to integrate new techniques and/or organizational structures into their thinking patterns and everyday life for entrepreneurs, and to use new products for consumers [GAG 11].

Let us look at innovation within local farming in developing countries, which encounters two types of difficulties:

- innovation is most often perceived by researchers, engineers and even farmers as a new technique – “object innovation” – without considering the intangible nature of certain components of innovation. The debates between these actors then focus on the technical and economic performance of new techniques without addressing the real needs for innovation and the conditions for change;

- alluding to innovation theories from the world of business [AKR 88, LE 06, GAG 11], innovation is determined relative to decisions made by the individual “farmer”, who is considered as an entrepreneur that acts alone. Excluding the learning processes, there has been little work done to address the issue of collective action or coordination between farmers and other actors as the building blocks of an innovation process.

Considering these two layers of difficulty, let us first explore the innovation processes underway in the market gardening sector of Senegal’s main vegetable-producing region, the Niayes (Figure 6.2). We will examine the origins of these processes, particularly with regard to the agro-ecological transition. In our discussion, we will broach the need to (1) understand the farming or endogenous innovation processes and (2) identify and accompany the innovation systems that are already in place.

6.3. Methodology

6.3.1. Context

The Niayes region, on the West coast of Senegal between Saint-Louis and Dakar, stretches over 180 km with a width varying between 5 and 30 km
(Figure 6.2). The Niayes are located in the regions of Dakar, Thiès, Louga and Saint-Louis, which in 2001 totaled 5.5 million inhabitants or 52.5% of the national population with an average density of 193 inhabitants per km² [TOU 05]. This demographic concentration was accompanied by rapid urbanization on the outskirts of Dakar, gradually engulfing areas that had up until then been used for agriculture. Although it only had a modest annual rainfall of less than 200 mm on average in the North and 400 mm in the South, the Niayes had until then benefited from favorable conditions for irrigation due to the presence of shallow groundwater aquifers. This hydraulic peculiarity explains the history in this region of market gardening and arboriculture for the national market. Its proximity to the port and Dakar airport has more recently led some investors to turn to the production of mango, green beans and cherry tomatoes for exportation to Europe. This study on innovation processes was conducted in the rural communities of Keur Moussa and Kayar-Diender (Figure 6.2).

Figure 6.2. Map of the area of study and North-Western part of Senegal. For a color version of this figure, see www.iste.co.uk/temple/innovation.zip
6.3.2. Combination of methods

The methodology used in this study combines analyzing farming practices [GAF 07] and tracking innovations [SAL 12]. Surveys were carried out with 22 farmers about their decisions and reasoning for crop technical management, developments and how they achieved routine or innovative practices (Box 6.1). Innovative practices were identified using networks of agricultural technicians in the study area as well as through farmers responsible for professional organizations in order to identify market gardeners considered by their peers as innovators. The study area was the one targeted by our partner NGO ENDA-PRONAT\(^1\), the rural communities (RC) of Kayar Diender and Keur Moussa, which are located less than 40 km from Dakar. In the first district, ENDA and the Diender Federation of agro-pastoralists have been promoting the “healthy and sustainable agriculture” model (abbreviated as HSA) for several years by developing training courses, teaching fields and specific support to facilitate the supply of organic inputs. In the second district, the same NGO recently started working in the same way with the Woobin Federation. These actors have designed an HSA specification for Senegal that is fairly close to that of organic agriculture in Europe but without a certification or participatory guarantee system. ENDA has supported the establishment of a marketing cooperative for HSA products, mainly vegetables, called Sell Sellal, which operates in a few districts of Dakar. For some years now, this NGO has been developing its actions to support the agricultural sector based on the concept of agro-ecology (Box 6.2) for both production and marketing, by bringing consumers closer to producers [END 10].

The scheme only concerned the rural communities of Kayar-Diender and Keur Moussa, which were compartmentalized. Thus, three agro-ecological groups were considered:

- real Niayes: sandy soils with localized accumulation of organic matter at the bottom of depressions and easy access to water;

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\(^1\) http://www.endapronat.org/index.php?lang=fr. ENDA-PRONAT is the environmental branch of the Senegalese NGO ENDA Third World, which was set up in 1972 for training and support projects for Senegalese farmers. It also defends the values of the family farming model and fights against the seizure of agricultural land. ENDA Third World has become an international network that is present in about ten developing countries. In the rest of this
- dried out valley and lake: fertile soil with a predominantly clayey soil, risk of surface clogging during the rainy season, difficult access to irrigation water because of its depth;
- fixed dunes: unleached tropical soils, not very fertile, deep water but water distribution by pipeline for market gardeners.

Twenty-two producers were identified in these three zones according to the method described above. Then, once they had agreed to participate, they were surveyed between May and August 2016 during two semidirective interviews per producer (sometimes a third interview was necessary). The duration of each interview did not exceed 1 h 30 min. Three topics were discussed: the history and the trajectory of their farm, the environment, structure and organization of their farm today, and finally, the functioning of their market gardening cropping system and the reasoning behind their choice of technical practices.

**Box 6.1. The survey mechanism**

Agro-ecology is a polysemous term [WEZ 09, INT 13]. It was a new scientific discipline that combined agriculture and ecology; it was a set of practices and a social movement. The aim was to systemically design forms of sustainable agriculture by considering (1) production practices that respect the environment and human health [DUR 15], (2) an organization of sectors and territories that did not marginalize certain categories of rural people, (3) fair and innovative forms of marketing and (4) the recycling of by-products and waste (notion of circular economy). Agro-ecology does not correspond to standardized specifications.

Agro-ecological transition is defined as the progression of an agriculture that already uses chemical inputs and/or degrades the environment toward a more sustainable agriculture. It then comes down to a question of proposing alternatives to producers based on (1) natural processes such as the introduction of herbaceous or tree legumes [CHE 06] and (2) substitutes for chemical inputs (biopesticides, mechanical barriers in net or plastic film, etc.). When there is no alternative to these inputs or mechanizations, farmers can always use synthetic
Box 6.2. Agro-ecology and the agroecological transition

6.4. Results: diversity of technical innovation processes

6.4.1. Adoption and adaptation of an innovation from large capital-intensive farms: drip irrigation and electric pumping

For many West African agricultural development actors, localized or “drip irrigation” was considered too complex and expensive to be adopted by small market gardeners. Although the installation of supply pipes in plots and those with drippers was easy enough, for irrigation to be carried out properly, it was advised to take particular care when filtering the water and to ensure homogeneous pressure throughout the irrigation system. In addition to this, pressure had to be applied to the water before driving it into the irrigation system, either directly using a heat pump or an electric pump, or by storing it in a raised basin a few meters above ground level. In the past, many drip extension projects in Senegal and Burkina Faso failed because they required manual dewatering and elevation of water.

Today, the adoption of this technology by a group of Niayes market gardeners and more generally in Central and Northern Senegal is effective. The innovation process that has allowed this is defined by a combination of three major determinants:

- the proximity of these small market gardeners (sometimes less than one ha) to large capital-intensive farms that produce crops for export to Europe in winter and early spring (melon, green beans, cherry tomatoes, etc.). These companies have imported drip equipment from Europe or the Middle East and have qualified installation technicians at hand, in addition to having systematized the use of electrical energy for irrigation. The skilled workers of these agricultural companies acquired the know-how of this sector and were able to make it available to small market gardeners. Sometimes these were even one and the same. These large farms initially sold or donated part of their user equipment;
- the sharp drop in price of the heat pump imported from South-East Asia facilitated the installation of certain family farms. For others, rural electrification, which is still very partial, has made it easier to extract water from great depths (beyond 10 m and sometimes up to 100 m deep) and to put it under pressure. The purchase price and maintenance cost of an electric pump is even lower than that of a motor-driven heat pump with equivalent pumping depth;

- market gardeners and craftsmen in villages and rural towns have shown strong capacities to adapt this drip technology by tinkering with filters and fertigation systems without always resorting to relatively expensive imported materials.

These adaptations of the innovation, which were initially thought to be complex and costly, have allowed it to be diffused in farms such that they could be well-equipped and thus abandon manual irrigation work, which was very labor-intensive and tedious. The main impact of this “do-it-yourself” innovation was the increase in cultivated and irrigated area per farm and per family worker, for those with sufficient land. Specialization and simplification of cropping systems with less than five crops was observed, with an emphasis on onions during the dry season.

6.4.2. An innovation process led by a development operator: the use of biopesticides and organic manure

The agro-ecology promoted by ENDA on a Senegal-wide scale was mainly applied to market gardening in the above-mentioned centers. This was because of the ideological positioning of the NGO, the observations it was able to make in the past [END 10] and the new expectations of consumers. Today, there is a real mistrust among farmers regarding the sanitary quality of vegetables, which can be contaminated by pesticide residues, heavy metals and sometimes germs and bacteria contained in irrigation water that has been polluted by wastewater. This mistrust is fueled by the government’s failure to take sufficient action against sellers and users of unregistered or fraudulently imported pesticides from South-East Asia or Nigeria.

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2 The aim is to inject a mineral fertilizer solution into the irrigation network.
By developing an HSA network, the NGO ENDA aims to improve the quality of basic food products, the biological functioning of agro-systems and the quality of life of farmers who would no longer need to use chemical inputs. For this purpose, technicians defined a technical reference for the production and use of organic manure and biopesticides\(^3\) instead of mineral fertilizers and chemical pesticides. This reference mainly stems from experimental work carried out in sub-Saharan Africa by various NGOs including ENDA. Only recently has public research focused on the issue of substitution of chemical inputs by organic inputs. Based on this standard, ENDA facilitators and technicians offered volunteer farmers the opportunity to attend information and training sessions on agro-ecology. Farmer school fields have been set up and are co-managed by the NGO and other producer federations. ENDA’s agro-ecology project also provides material support for the production of HSA by women’s groups in collective gardens (solar pumping) for supplying biopesticides and for marketing part of the harvest via the Sell Sellal cooperative.

At present, HSA market gardening has been substituting chemical inputs with natural or organic inputs that have been produced on the farm or purchased. Due to a lack of research support, ENDA has not been able to start a real process of re-designing cropping systems. Therefore, we have not seen any innovative cropping systems emerge that would break with conventional systems. ENDA’s technicians have proposed crop associations combining a main market gardening crop (cabbage, tomato) with a secondary crop such as basil, which can be sold as a condiment but has a repellent effect on various insect pests. In addition, the number\(^4\) of combined market garden species in the plots managed through HSA has not changed much. In the northern part of the study area, in the traditionally sandy Niayes area [KET 16], diversification is a dated process because the surface area per market gardener is very small and the number of cropping

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3 Biopesticides are made from living materials, plants or microorganisms. The most common ones are based on neem extracts (Azadirachta indica): oil is extracted from seeds, liquid manure is made with dry leaf powder or fresh leaves. These products repel or kill certain insects. Natural repellent products are made with garlic or chilli pepper. In Europe, biopesticides must be registered for use in agriculture. In Senegal, there is no registration and there are even less specific recommendations for the use of biopesticides manufactured on the farm, which can lead to risks of poisoning livestock and microfauna.

4 Indicator of crop system change. Agro-ecology is partly based on increasing cultivated biodiversity by ensuring that the combined crops are compatible with each other and with the rotation of crops.
cycles per year then needs to be increased in order to obtain sufficient income. In the central part of the study area, the more clayey floodplain, the specialization induced by the adoption of drip irrigation preceded the extension of HSA. But producers did not go backwards and instead only adopted HSA on a small section of their market garden land, mainly for dry season onion.

Producers’ interest in HSA market gardening varies from one area to another. But in all cases, the promise of improving their income through a shorter marketing channel takes precedence over their quality of life or the goal of preserving the environment and consumer health. Moreover, we saw a few market gardeners in the northern zone (Keur Diender RC) who had converted all of their produce into HSA; these market gardeners can be described as “convinced” and “militant”. In other cases, especially in the center and the South, producers were more attentive or opportunistic in that they produced HSA on small areas of their land (1) to maintain a link with ENDA projects and the Sell Sellal marketing cooperative in case the demand for vegetables increased massively and (2) to benefit from advantages provided by these projects such as the supply of seeds and organic or conventional inputs (mineral fertilizer).

The influence of HSA market gardening on farms therefore varies greatly depending on the localities and the type of farm. For example, in the floodplains where drip irrigation has been widely adopted, producers cannot convert their entire onion-growing area into HSA (2–3 ha, or nearly 100 tons of product) because the Sell Sellal cooperative is not in a position to buy such large quantities. There are no other marketing channels for a high-quality onion that is more expensive to buy for the consumer. In addition, according to our surveys, the HSA onion costs a little more to produce because (1) its duration of cultivation and therefore irrigation increases by 2 weeks and (2) it requires large quantities of manure that is expensive to transport. The HSA yields are considerably lower than those of conventional onions because fertilization with organic manure is more difficult to control than with mineral fertilizers, especially at the beginning of the conversion. In addition, there is also a significant risk in HSA of

5 The two federations of producers resulting from ENDA’s work organize the supply of fertilizer on credit to their members. Even if they are involved in the HSA project, they consider that conventional production, which remains by far the most significant quantitatively and financially, should be supported.
insufficient control of pest attacks with biopesticides, unless a large amount of time-consuming biopesticide sprays (manual spraying) and silver sprays are carried out (for example one could purchase \textit{Bacillus thuregensis}-based bioinsecticides) [KET 16].

6.4.3. Poorly visible innovations carried forward by market gardeners

Our surveys and field visits have highlighted several “farmer” innovations [DUG 06, DUG 16] that were designed and developed by a few market gardeners through conventional production or HSA. These include new crop combinations in market gardening and the abandonment of pure crops. Two forms of combinations of cucumber and eggplant were identified (Figure 6.3).

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{eggplant_cucumber_combination}
\caption{Spatial arrangement of eggplant (violet) and cucumber (green) in a combination. For a color version of this figure, see www.iste.co.uk/temple/innovation.zip}
\end{figure}

In the first case, the cucumber is sown in the dry season directly in the plot. At the time of production, well-developed eggplant are transplanted in
staggered rows between the cucumbers (Figure 6.3a). The production of cucumber continues throughout May and June, and then the plant is pulled up because it can barely withstand the rains that begin in July. At this time, the eggplant begins its production, which lasts until October or November (Figure 6.3b). In the second case (Figure 6.3c), the eggplant is first transplanted at the beginning of the dry season (October/November). The cucumber is sown 15 days later between the eggplant roots. Both crops come into production at the same time and the harvest time is longer than in the former case.

In both situations, the aim is to increase income per unit area by making the best use of the available space, which for some market gardeners is very limited. Finally, another advantage highlighted by these innovators is that the cucumber covering the ground during eggplant growth limits the amount of weeding rounds required, which are replaced by frequent passages on the plot to guide the growth of the cucumber and allow the eggplant to not be suffocated by the cucurbit. Other crop combinations have also been seen: cabbage + eggplant, cabbage + jaxatu (African eggplant), cucumber + okra—all of which constitute very localized farmer innovations without any noticeable diffusion process to date.

![Figure 6.3b. Combined crops, cucumber in the dry season and eggplant in the rainy season. For a color version of this figure, see www.iste.co.uk/templet11novation.zip](www.iste.co.uk/templet11novation.zip)

![Figure 6.3c. Combined crops, cucumber in the dry season and eggplant in the dry and rainy season. For a color version of this figure, see www.iste.co.uk/templet11novation.zip](www.iste.co.uk/templet11novation.zip)
Rain-fed crop combinations in market gardening were common practice in the past in hut gardens, which were mainly for feeding the families of farmers. With the rise in irrigated market gardening during the dry season, which was accompanied by research and the appearance of advisory support structures, the combination of market gardening crops and rain-fed market gardening have greatly regressed in favor of pure crops. This technical decision was justified by agronomists to ensure better management of crop fertilization (with fertilizers) and better pest control using chemical pesticides, which are often specific to crop families.

The few innovative producers who did recently develop vegetable crop combinations justified their choice by:

1) the scarcity of irrigable land due to the increase in the number of producers (immigration, urban investors) and the division of family farms following the death of the farm owner. On a smaller surface area, the producer must optimize the use of available land throughout the year, since water supply to crops is no longer a limiting factor with irrigation situations. For this reason, combining market gardening crops is a feasible strategy;

2) the high cost of fertilizers for which the prices are steadily rising. Producers believe that by splitting fertilizer inputs, they use less fertilizer than if they grow both species on separate plots. Two crops with different root systems (cucumber with shallow rooting, eggplant root with a deep pivot) will explore different soil depths and thus limit nutrient loss through leaching.

On the other hand, none of the surveyed innovative farmers mentioned a decrease in pest pressure for crop combinations. This aspect should be studied by monitoring pest populations over time and the prevalence of fungal diseases to assess the most relevant combinations in the face of increased parasitic pressure.

In the register of crop combinations, we must highlight a breakthrough innovation: the combination of market gardening and arboriculture. This innovative cropping system can combine mango, orange or mandarin trees and market garden crops, on the same plot and over time (over the life span

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6 In the past, vegetables were grown without irrigation during the rainy season to improve the family's diet. Some vegetables such as okra were dried to be preserved during the dry season.
of fruit trees). This farming innovation has not been yet researched in detail in Senegal and probably requires better definition of ad hoc planting densities, the development of fruit tree pruning techniques to limit shading without affecting the yield too much and the selection of vegetable crops that are not overly sensitive to shade. In this case too, agronomists must engage in a dialog with innovative arbo-market gardeners to understand their technical and economic logic and assess the effects of this type of combination on soil fertility, circulation and valorization of irrigation water and the dynamics of pest populations and crop auxiliaries [GAB 15].

6.5. Discussion

6.5.1. Recognizing the innovation capacities of farmers

The diversity of innovation processes highlighted by this case study shows the need for engineers and decision-makers to reconsider or even abandon the linear model of innovation. This model considers the supremacy of researchers and engineers over other actors in innovation processes. In the industrial and service sectors, innovation is no longer seen as the result of a formal innovation system alone, i.e. one that is institutionalized and administered. There is a growing preference for encouraging exchanges between emerging players such as start-ups, clusters of SMEs, etc., that encourage creation and bring together designers, users and decision-makers [SUI 08]. In the agricultural sector, and especially in developing countries, poorly organized and poorly regarded producers, craftsmen and traders are rarely taken into account in projects to design and promote innovation. The asymmetry between actors and engineers and researchers in terms of academic knowledge, of understanding an international language (English, French) and of mastering communication tools leads to a pre-eminence of “graduates” in these projects and in discussions with decision-makers. This asymmetry is accentuated by the role played by representatives of donors and regional and international research institutions in the management of innovation programs.

In order to overcome this misunderstanding, which confuses invention and innovation, objective deconstruction must be done in order to get rid of the top-down, technical and diffusionist “developmentalist” ideology that is still present in agricultural development programs. First of all,
decision-makers, engineers and researchers must recognize and know how to identify the innovative capacities of those who are changing their production systems – farmers and their close allies (craftsmen, technicians, traders). But this recognition must not neglect the fundamental role that agricultural service agents (research, training, extension, private services, etc.) play in supporting the innovation processes desired by farmers. These agents must remain a source of suggestions, suppliers of new ideas and inventions, and be curious about what the farmers themselves have undertaken in this field. It would be utopian to believe that all problems in the agricultural world can be solved by farmers alone without outside intervention or public policy.

This forces engineers to look at complex systems and not just technical changes. Thus, managing operations and collective action (farming organizations, management of common territories and resources, organization of services) are recognized as research topics and intervention levels for innovation. The products expected from research are therefore not only inventions but also methods/approaches to accompany innovation processes. Thus, codesigning or coproducing innovations implies a change in the attitude of researchers and engineers, who must be prepared to accept confrontation and exchanges with other actors in the innovation process. From this lesson arises the concept of an innovation system [TOU 14], which recognizes the plurality of these actors, their mutual enrichment and the importance of learning processes between actors of different origins.

6.5.2. Why should agronomists be interested in farming innovation?

In the market gardening farms of Niayes, we identified innovation processes “led” by development organizations (transition to healthy and sustainable agriculture promoted by ENDA) and others, either totally or partially coming from the farming world (drip, vegetable crop combinations, arbo-market gardening, etc.). Agronomists, whose mission is to assist in decision-making (guiding public policies) and to support and enrich innovation processes, must first take the time to analyze emerging endogenous innovation processes (Table 6.1). This is an intelligent way of understanding farmers’ expectations and needs, since these processes correspond to a commitment (individual or collective) on their part.
<table>
<thead>
<tr>
<th>Type of innovation process</th>
<th>Origin of the invention and period of emergence</th>
<th>External support to the farming community</th>
<th>Investment and production costs</th>
<th>Ease of use</th>
<th>Adoption/diffusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Localized irrigation (drip)</td>
<td>Exogenous (large exporter market gardening companies importing equipment) 2000–2005</td>
<td>Limited (skilled workers)</td>
<td>High for equipment and operation (energy)</td>
<td>Easy</td>
<td>Broad in the category of relatively well-off market gardeners</td>
</tr>
<tr>
<td>Healthy and sustainable agriculture (HSA)</td>
<td>Europe (organic food chains), in Senegal: NGOs, foreign consumers. 2005–2010</td>
<td>Project technicians and NGOs</td>
<td>Medium (cost of bioinputs)</td>
<td>Difficult</td>
<td>Low</td>
</tr>
<tr>
<td>Combination of market gardening crops</td>
<td>Endogenous 2000–2015</td>
<td>None</td>
<td>Low</td>
<td>Easy</td>
<td>Low to very low</td>
</tr>
</tbody>
</table>

Table 6.1. Comparison of three innovation processes studied
Moreover, farming innovation can be a source of inspiration for agronomists who are involved in codesigning innovative agricultural systems. In France, for example, some farmers adopt alternative production methods (organic farming, low-input agriculture, conservation agriculture without ploughing) and are thus inventors or drivers of the innovation process [GOU 12]. In order to enrich the design processes, agronomists have an invested interest in studying current and past changes on the farms of innovators, which Salembier and Meynard [SAL 13] called “innovation tracking”. This way of doing agriculture is all the more important when the scientific literature is not able to provide references on certain phenomena (interaction between crops and biocenosis in the case of crop combinations) or when there is no funding to carry out multiple rounds of trials in experimental stations, sometimes over a long period of time. New approaches to the design of innovative cropping systems then combine tried-and-tested methods (analysis of practices, regional yield gap diagnosis, sociology of innovation) and more novel ones (modeling of cropping and production systems, partnership action research, pursuit of innovation). Although agronomists and the groups of actors that accompany them find new ideas by studying the innovative practices of certain farmers, they also have to analyze these practices and their impacts on the performance of production systems and on the different elements of the environment (soil, water, air, etc.). Farmers have good reasons to do what they do, but their practices and new ways of producing must also be discussed because they can be improved.

Four areas of action research are worth considering:

- Continuing to evaluate the innovations presented above, in particular crop combinations and biopesticides, what are the effects of these innovations on the management of parasites and fungal diseases? What are the production costs (financial, labor) and benefits compared to traditional cropping systems? Do these innovations improve the resilience of production systems in the face of climatic hazards?

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7 For example, the design of perennial arboricultural systems requires a long period of experimentation and observation (10 years or more), before scientifically indisputable references can be obtained.
- Monitoring in order to identify other emerging innovations coming from family farms, companies or programs steered by research and development structures (solar pumping, arbo-market gardening, etc.).

- Specifying the effects of different types of organic manure in terms of nutrient inputs to crops, activation of biological soil life and soil pollution by undesirable products such as heavy metals or antibiotic residues used in intensive livestock production.

- Experimenting with spaces for conversation between innovators of different origins (producers, processors, craftsmen, industrialists, researchers) like a local fair for agricultural innovation, and evaluating the impacts in terms of learning and technical changes.

Box 6.3. Leads for further research on innovation in the Niayes region

6.5.3. How to support innovation processes?

The success of innovation processes in terms of problem solving, performance improvement and the diffusion of innovation is not unrelated to the structure and functioning of combined innovation systems. In the case of market gardening crop combinations, we identified very few innovative farmers despite the fact that the innovation is inexpensive and easy to use. Although it is more specific to farms with significant land constraints, it is still common in the Niayes. In this case, innovative farmers are likely to be socially isolated or unwilling to share their invention in order to be the sole beneficiaries. In addition, other market gardeners may consider crop combinations to be from another era, since agronomists and technical advisers have been advocating pure crops for over 30 years [CDH 87].

Conversely, the spread of drip irrigation has shown great dynamism over the past decade, despite that many agronomists and public decision-makers still consider that this technology is not within the reach of small local farms. In the Maghreb [AME 13, BEN 16, DUG 14], the innovation systems associated with the Niayes' drop by drop system are multistakeholder and dynamic because they bring together market gardeners, skilled workers, craftsmen and traders, who all have an invested interest in seeing this technology widely propagated. In these two cases of innovation, researchers and developers are almost absent from innovation systems. In Senegal and in...
the majority of sub-Saharan countries, the ratio of researchers to farmers and
advisers/farmers is much lower than in developed countries. Farmers are
therefore often left to innovate for themselves, individually or in small
groups.

In this context, how can we support these successful endogenous
innovation processes without significantly changing the innovation systems
that support them, and which have already proven their worth? What forms
of support should be developed so that these processes make farmers and the
horticultural sector even more successful? Here again, the worsening
guidelines and attitudes of agronomists must give way to the principles of
action research in partnership [COU 14]. To standardize these processes, to
regulate and frame them would be counter-productive and would counter
current theories on the accompaniment of innovation. Moreover, since the
farmer/adviser ratio is unlikely to increase, after the co-design phase of
innovations, “Farmer to Farmer Extension” approaches should be
disseminated, which requires the adviser to adopt a position that no longer
prescribes collective extension actions but instead moderates them [KIP 14].

In this context, evaluating these innovations according to an array of
social, economic, agricultural and environmental indicators remains a basic
activity carried out by agronomists and other scientists [TRI 15, TEM 16].
But for this to happen, two channels for improvement must be considered by
all stakeholders:

- methods for evaluating and measuring the effects and impacts of
innovations must progress and be more accessible and easy to use (cost,
duration);

- these methods must be more participatory and must incorporate
farmers’ points of view, otherwise they risk being seen only as tools for
monitoring, sanctioning and supervising farmers’ initiatives.

6.6. Conclusion

The development of the market gardening sector in Senegal, and
particularly in the Niayes region, was accompanied by a series of innovation
processes that mainly concerned production systems and few downstream
activities. These processes can be driven by development actors, in particular
researchers and project engineers, but also directly by farmers without the
support of people outside their production area and innovation system. To date, the innovation processes carried out by market gardeners are primarily aimed at improving the value of the available irrigable surfaces, in situations of very limited land (combinations of crops, arbo-market gardening) or somewhat limited land (drop by drop). The agro-ecological transition of these production systems is mainly pushed by NGOs and certain research projects, but it is not yet the subject of a proactive public policy.

From a technical point of view, the “agro-ecological” market gardening practiced by some farmers was born from the substitution of chemical inputs with natural inputs, as accepted in organic farming. To date, industry players, particularly researchers, have not yet redesigned cropping and production systems to achieve breakthrough innovations. The concept of an agro-ecological transition in agriculture calls for going beyond the substitution of chemical inputs. It requires implementing (1) processes for redesigning production methods and (2) new ways of coordinating and learning between actors in the supply chains and territories [DUR 14]. It is therefore an innovation process that combines agricultural, socio-economic, organizational and institutional changes.

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