What contribution of agroecology to job creation in sub-Saharan Africa? The case of horticulture in the Niayes, Senegal

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Accpeted in *Agroecology and Sustainable Food Systems*

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Abstract: In the context of Sub-Saharan Africa's demographic boom, the issue of youth employment has become a major concern. Many debates are ongoing regarding agriculture's role in the structural transformation process and providing jobs. In this regard, we explore the opportunity of an agroecological intensification of family farming. We analyze data from agricultural households in the Niayes area of Senegal collected in 2019 and use a clustering method to group farms and rank them according to agroecological practices. Diversity and livestock integration are the most differentiating factors across the identified farming systems. Considering labor allocation complexity within family farms, we compare employment indicators between farming systems to look for agroecology's effect on agricultural work. We observe diversity in the intensity of labor requirements across the different systems but no overall increase for the most agroecological. However, women working hours appear significantly increased for two groups suggesting a substitution with wage workers for the most agroecological systems.

Keywords: agroecology, employment, sub-Saharan Africa, labor, family farming, farming systems

Introduction

The ongoing demographic boom in sub-Saharan Africa (SSA) raises the question of youth employment, as, by 2040, 400 million new workers will be looking for a gainful activity in the region (Fox and Gandhi 2021). A lack of job opportunities to meet the needs of these young generations could have dramatic consequences and lead to economic stagnation, disillusionment, and social unrest (Yeboah and Jayne 2018). According to the most optimistic projections, only a quarter of the youth will be able to find salaried work within the next decade (ibid).

Nowadays, sub-Saharan African countries' agricultural sectors still account for an 18% average of the region's GDP (World Bank 2020) and currently employs 60 to 75% of the population in rural areas (African Development Bank 2019). Informal employment is widespread, and the prospects for rapid industrialization, which would quickly create jobs, are slim (Rodrik 2018; Diao, McMillan, and Rodrik 2019).

In this context, rural areas will be specifically exposed to the demographic boom (Girard 2020). In addition, it is believed that the young population might not follow a pattern of rural exodus as the economic opportunities in urban areas are declining. Jayne, Yeboah, et Henry (2017) highlight the need to consider the rural-to-rural migrations to estimate the future rural population, as internal migrations have evolved in the last decades (Mercandalli 2015; Mercandalli and Losch 2018). Hence, rural population growth should maintain over time, and the political responses will have to focus on rural areas, especially for the agricultural sector.

Debates on the structural transformation trajectories of SSA's countries often oppose the tenants of quick industrialization and the advocates of a broad agricultural-based development. Within them, confronting views exist on how the agricultural sector could contribute to economic growth and thus its place within the job creation process (Diao, Hazell, and Thurlow 2010; Dercon and Gollin 2014). Several debates are taking place regarding the compared advantages of family farming and agro-business or the opportunity to promote more sustainable agricultural practices through agroecology.

Land degradation, sustainable development, and climate change have driven researchers and NGOs to advocate for an agroecological intensification (Altieri 2009; De Schutter 2011; Tittonell and Giller 2013; IPES-FOOD 2018). Several local initiatives promoting agroecology have emerged within SSA's countries. The FAO started seminars on agroecology in 2014 and launched the Second International Symposium on Agroecology in April 2018. The latest High-Level Panel of Experts on Food Security and Nutrition report released in July 2019 is about agroecology and sustainable agricultures (HLPE 2019). Research is also conducted on the subject by the IPES-Food expert panel, the Alliance for Food Sovereignty in Africa, and the ProIntensAfrica and LeapAgri European Programmes (Sourisseau et al. 2019).

We hypothesize that the development of agroecology in family farms could contribute to absorbing labor in the context of the demographic boom and low employment of SSA. Indeed, the current knowledge regarding agroecology reports an increase in the workload due to changes in agricultural practices requiring more precise and targeted interventions (Temple et al. 2008; Côte et al. 2019). Many existing analyses deal more specifically with conservation agriculture rather than agroecology (Nana et al. 2014; Montt and Luu 2020). Regarding this latter, the increase in labor is often pointed as an obstacle to adopting the practices but is rarely precisely measured within the agronomic evaluation of the practices (Dugué et al. 2011 ; Levard and Mathieu 2018).

We postulate that this additional work might increase the need for agricultural workers and job creation. However, the job creation process is not an internal process relying on technical choices but is inherently dependent on the local institutions of labor mobilization, including the labor market, within which the agricultural workers evolve (Michel and Oudin 2003 ; Darpeix, Bignebat, and Perrier-Cornet 2014). In this regard, job creation in agriculture is highly context-dependent.

From an employment perspective, there are barely any studies regarding agroecology and its impact on hiring. Indeed, work content and employment are two different things, and the increase in workload which is witnessed might not reflect an increase in farm employment. Quantitative analyzes regarding the effect of organic farming on employment conducted in western countries find a significant positive effect (Midler, Depeyrot, and Detang-Dessendre 2019). A few studies focused on labor requirements of other types of sustainable agricultural practices in sub-Saharan countries and found a significant work increase related to adopting these new practices (Montt and Luu 2020; Pereira Fontes 2020).

This paper aims to expand the knowledge regarding the opportunity of job creation within the development of agroecology, more specifically in rural SSA, based on agricultural households data from Senegal collected in the Niayes area in 2019. Quantitative analyses are conducted on a sample of 165 households. The farms are classified from an agroecological perspective using a clustering-based methodology to go beyond the distinction between conventional and organic. The groups of different agroecological levels are then compared to evaluate their employment and labor requirements variations. Our results do not indicate a positive effect of agroecology on job creation, yet we find evidence of change in work organization based on increased women labor and wage labor decrease.

The first section explains the issues of the structural transformation of SSA's countries, the agricultural sector's role in this process, and the potential for agroecological intensification. The second section describes the context of Senegal regarding agroecology and the methodological issue of measuring job creation in agriculture; the third section describes the data and the methodology of data analysis used; the last section presents our results.

1 Structural transformation of Sub-Saharan Africa's countries and agroecology

Discussing the role of agriculture regarding employment and economic development in SSA leads to examining the structural transformation trajectories of its countries. As first described by Lewis (1954), the structural transformation process involved the transformation of the economies through a change in inter-sectoral labor distribution. From an agriculture-based economy, the productivity gains in this sector trigger an inter-sectoral labor transition towards more productive sectors, such as industry, allowing the economy's overall productivity to increase. Hence, from a structuralist point of view, the labor productivity of the economic sectors and the labor allocation directly impact job creation and economic development.

Through the increased labor productivity in agriculture, many see the opportunity for sub-Saharan African countries to follow trajectories similar to the western countries. It is also because of agroecology's supposedly low labor productivity that it is disregarded as a viable economic alternative path to development. For these reasons, we examine the ongoing state and discussions on structural transformation in SSA and the potential implication of agroecology labor productivity on this process.

1.1 Structural transformation trajectories and the opportunity for an agroecological intensification

Taking stock of the structural transformation process in SSA

Jayne, Chamberlin, et Benfica (2018) take stock of Africa's structural transformation progress and note that there is no overall development of the manufacturing sector despite significant differences across countries. A shift in labor distribution from agriculture to informal goods and service sectors seems to be occurring; however with no productivity gains (Diao, McMillan, and Rodrik 2019). Furthermore, Jayne, Chamberlin, and Benfica (2018) find the 'urbanization without industrialization' scenario, which takes place in certain countries, to be the most alarming as it is not based on any economic dynamic of sectoral development. Hence, the growth observed over the last decade on the continent displays an overall low employment content (Gueye and Mbaye 2018).

Although considerable progress has been witnessed in the region since 2000, as shown by the increase in the youth education level, the improvement of governance, and the per capita GDP mean (Jayne, Chamberlin, and Benfica 2018), the African economies do not appear ready to absorb the expected cohorts of newcomer workers. The changes are of varying intensities across countries; among them, some do not seem to be showing signs of similar progress. Furthermore, the sustainability of the observed changes is questioned as they have been resting on easily reversible trends, such as primary commodity price booms, without involving structural modifications like industrialization or poverty reduction (ibid).

The role of agriculture in the structural transformation process

Given the predominance of employment in the agricultural sector, many among the development community advocate today for an agriculture-based growth, seen as more inclusive and with better multiplier effects (Mellor 2018). They support agriculture productivity gains to set the structural transformation process in motion by adopting similar technical packages like the one promoted for the Green Revolution (Jayne, Yeboah, and Henry 2017; Jayne and Sanchez 2021). In their case, supporting farmers' development is a pathway for transitioning economies out of agriculture. This dominant thinking translates into generalizing input subsidies policies across SSA (Jayne et al. 2018). The Alliance for a Green Revolution in Africa (AGRA) was launched by the Rockefeller Foundation and the Bill & Melinda Gates Foundation in 2006. Since then, this organization has been an active promoter of agricultural productivity increase through the adoption of these technical changes by African farmers (Toenniessen, Adesina, and DeVries 2008).

However, some economists have started to question the possibility of a structural transformation of SSA economies following the Lewis path and instead suggested that other trajectories should be considered (Dorin, Hourcade, and Benoit-Cattin 2013). Globalization has profoundly modified the balance of power, and SSA economies face increased international competition and a challenged state position due to liberalization ideology (Losch 2014). The absence of industrialization and the weak prospects for one in the short term set aside the possibility for the secondary sector to absorb the upcoming labor the way it happened in Western countries (Rodrik 2018). Besides the low socio-economic probability of this replication, climate change exerts further pressure on food systems already pushed to their limits (Steiner et al. 2020). SSA's smallholder farms' ability to upscale to highly productive and resource-consuming conventional systems becomes even more limited, as rich nations' model relying on excessive resources and energy uses is not replicable given the earth's physical boundaries (Hickel and Kallis 2020; Hickel and Hallegatte 2022). This assessment led Steiner et al. (2020) to advocate for a rerouting of farming and rural livelihoods involving a "reinvigorated rural economy […] to spur agriculture to shift from being a direct (often subsistence) employer to a driver of rural development and growth".

Agroecological intensification trajectory

Integrating environmental constraints into the thinking on the future of agriculture thus adds another dimension to the debate on structural transformation paths for SSA. The necessity to intensify agricultural production without harming the environment gave birth to various approaches and concepts with blurred meanings (Wezel et al. 2015). Mockshell and Kamanda (2018) distinguish the proponents of a "continuation of technological advancements and intensive production systems with optimal input use through sustainable agricultural intensification (SAI) practices" and the advocates of a "paradigm shift to eco-agriculture, agroecology". These concepts have direct implications on how agriculture's role in development is viewed, as agroecological approaches mainly focus on land productivity improvement rather than labor's (Bernard and Lux 2017). Thus, maximizing production per hectare through synergies with the ecosystems, even if it involves more work, is accepted by agroecology's advocates.

Hence, the role of an agroecological intensification could be two-fold: first, intensifying agricultural production while preserving the environment; second, contributing to an alternative structural transformation trajectory for SSA by employing the youth coming from the demographic boom. Dorin, Hourcade, and Benoit-Cattin (2013), when examining structural transformations around the world, propose as a scenario for SSA an alternative “Farmer developing path” relying on a labor intensification of agriculture, i.e., an increase of the production per surface through land productivity improvement, that would absorb more labor. This scenario of structural transformation corresponds to an agroecological intensification.

As mentioned above, the allocation of labor towards the most productive sectors of the economy is critical for development according to the structuralist theory. Therefore, we examine the labor productivity of agroecology in the next section, as it has direct implications regarding economic growth and employment.

1.2 Agroecology and labor productivity

Agroecology’s many definitions

Agroecology has had multiple meanings since its creation, and Wezel et al. (2009) distinguish three: a science, a social movement, and a practice, illustrating a diversity of definitions and scales. The agroecological farming practices can be defined as “using intensively and in priority the ecological and biological processes” in farming practices (Griffon 2017), or as Côte et al. (2019) summarize it: “the optimization of biological and ecological regulation processes, the frugal management of resources, and the sustainable management of nutrient cycles”. However, for many, agroecology also conveys a political vision of society involving social dimensions at the food system scale (Gliessman 2016; Wezel et al. 2020). According to Gliessman (2013), the three dimensions (science, movement, practices) must be integrated “to avoid the eminent food crisis and establish a sustainable foundation for the food systems of the future”. This vision has led to the formalization of agroecology’s socio-economic principles within international institutions' frameworks (Wezel et al. 2020).

Ecosystem services mobilized by agroecology have been theorized in different ways. Hence, Balmford et al. (2008) highlight the need to differentiate between: the ecosystem functionalities or processes, ongoing in nature, and the ecosystem beneficial processes, from which human beings derive ecosystem benefits using labor and investments. Karsenty (2019) makes an even more precise distinction between the ecosystem services provided by nature and the environmental services provided by men when they maintain or enhance ecosystem services (such as water quality), this latter being an economical service.

The potential impact of agroecology on labor productivity

Agroecology’s characteristics imply specific task changes in farming, such as more observation of the agroecosystem, localized interventions, and adaptation to the local environment, but also in the organization of the work (Delecourt 2018). This diversity of tasks then requires more skills to perform them, which means a human capital increase (Temple et al. 2008, Jean 2011).

Some studies have found evidence of increased labor associated with agroecological farming practices. Montt and Luu (2020) study the labor requirements related to adopting conservation agriculture in five African countries Ethiopia, Kenya, Malawi, Mozambique, and Tanzania. They find an increased labor demand in households adopting conservation agriculture: this demand is met mainly by family labor and, more specifically, female labor. Pereira Fontes (2020) focuses on the effect of adopting Soil and Water Conservation practices on labor allocation in Ethiopia and finds a 31,4% increase in working days for adults and a 29% increase for children, going up to 78% for households with only three adults. These findings are consistent with an analysis by Bottazzi et al. (2020), concluding that agroecological practices adoption in Senegal leads to new labor control channels and paternalism; the additional work is often supported by the weakest groups, such as women and children. In other reports, mainly in the North, the farm operator handles the extra work, sometimes at the expense of his well-being, which

Galt (2013) describes as "self-exploitation". Dumont (2019) also observes critical working conditions for Belgian farmers in agroecology who struggle to make a living from their farms. The ideological commitment underlying agroecology's adoption explains why these farmers appear ready to accept non-decent forms of employment.

Although the work increase effect of agroecology seems to be relatively consistent, its impact on work productivity depends on these practices' yield. However, the results are not straightforward. Sanderson Bellamy and Ioris (2017) pointed out that there is no clear evidence regarding a yield gap between conventional and agroecological production systems. Most of the existing research focuses on studying the organic production system as they are easier to identify. The yield gap observed between organic and conventional farming using meta-analytic approaches ranges from 9% to 25% (Wilbois and Schmidt 2019). Results differ depending on the environmental or climatic conditions. For instance, organic yields might be more stable over time and space compared to conventional farming (Schrama et al. 2018). Moreover, in the context of degraded and poorly responsive soils, which cover large areas of SSA, agroecological intensification might restore the soil's organic matter, thus providing better yields than a conventional application of chemical input (Tittonell and Giller 2013).

Environmental services of agroecology

Even though evidence indicates an overall potential decrease in yield in agroecological farming, the environmental services provided must be considered to evaluate its labor productivity. Hence, Wilbois and Schmidt (2019) represented a conceptual model (Figure 1) to explain the magnitude of the gap between organic and conventional systems by integrating the output in terms of ecosystem services. Thus, ecosystem services appear to be a fundamental part of organic and agroecological systems results.

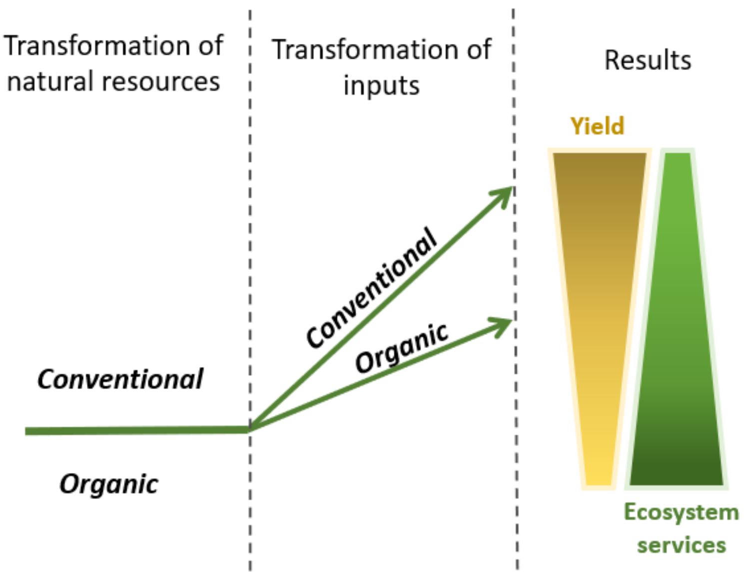


Figure 1. Simplified model to describe a cropping system as a process transformation (modified from Wilbois and Schmidt 2019)

To conclude, ecosystem services or environmental services being a critical output of agroecological farming, it is necessary to evaluate their value to assess its labor productivity. Ecosystem services valuation is a more and more integrated solution to preserve the environment, and a great variety of methodologies exists (Schröter et al. 2014).

1.3 Valuation of environmental service and job creation

For agroecology to lead to job creation, the valuation of the environmental service's additional work appears critical. Otherwise, farmers might either not be willing to engage in agroecology, facing an increased workload without economic retribution, or if they are, due to personal conviction, they might have to manage the extra work with family labor and overtime hours.

Thus, if governments consider an agroecological transition to absorb large numbers of workers, political measures supporting ecosystem valuation should be put in place. Markets improvements through the creation of labels (such as organic farming) or direct subsidies, such as payment for ecosystem services, are examples of relevant policies. A certified label and a functioning market allow organic production to be more remunerated than conventional farming. In this regard, the literature review conducted by Midler et al. (2019) on job creation related to organic agriculture in Western countries, where organic labels are well defined, shows an overall significant positive impact of organic farming on employment. As organic farming follows a similar trend away from conventional farming as agroecology, those findings corroborate a potential job creation linked to agroecological practices under the right conditions.

Our objective is to inform the opportunity for job creation in agroecology based on our results on its labor requirements in the Niayes area of Senegal. These potential employment opportunities could open new prospects regarding structural transformation trajectories for SSA.

2 Data collection and analysis

2.1 Agroecology in Senegal

In Senegal, as in many SSA countries, the issue of youth employment has become a critical concern. The agricultural sector still represents 15% of GDP and 70 to 60% of the employment, and for now, the exit of labor out of agriculture has been towards low productivity informal sector (Diao, McMillan, et Rodrik 2019). Thus, the role of agriculture in economic development and job creation in the country is admittedly crucial. Several policy programs to support job creation in agriculture have been launched within the last few years (FAO 2020).

Regarding agroecology, a national initiative was born in Senegal with the "Dynamique pour une Transition Agroécologique au Sénégal" (DyTAES) in 2019, after the announcement by the Senegalese President to make the agroecological transition a national priority (DyTAES 2020). This working group, composed of organizations and platforms engaged in agroecological transition in Senegal, released a report in January 2020 for the international event of "Les Journées de l'Agroécologie" held in Dakar. They introduced a number of recommendations to scale up the local agroecological projects led by community organizations, peasant organizations and NGOs.

As elsewhere in the world, the term agroecology in Senegal covers different types of farming with various levels of agroecological intensification. Thus, the distinction between so-called "alternatives" to conventional farming is not clear. Agroecology is often referred to as organic farming, or sometimes as "Agriculture Saine et Durable", a label created by the local NGO ENDA Pronat.

A national federation called the FENAB manages the development of "agriculture bio" (organic farming) in Senegal. The number of farmers committed to organic farming is most likely outdated, as local federations seldom communicate their number of adherents. However, they indicate the involvement of about 300 farmers in organic farming within ten organizations across the country. Only 40 of them are genuinely certified as organic (Bottazzi and Boillat 2021). The FAO knowledge platform on family farming indicates about 750 000 family farms in Senegal from a national survey of 2014. Even though that figure might have changed since then, it puts in perspective the scale of the conversion to organic farming in the country.

Enda Pronat, the Senegalese NGO previously mentioned, has been promoting agroecology for decades. They accompany local federations in four areas of Senegal to help farmers transition to agroecological practices. It is within two of these local federations in the Niayes area that our data was collected.

2.2 Data description

Our study zone is the Niayes area, located near Dakar in Senegal. Its agricultural sector is very dynamic and has specialized in fruits and vegetables production, mainly for the Dakar market.

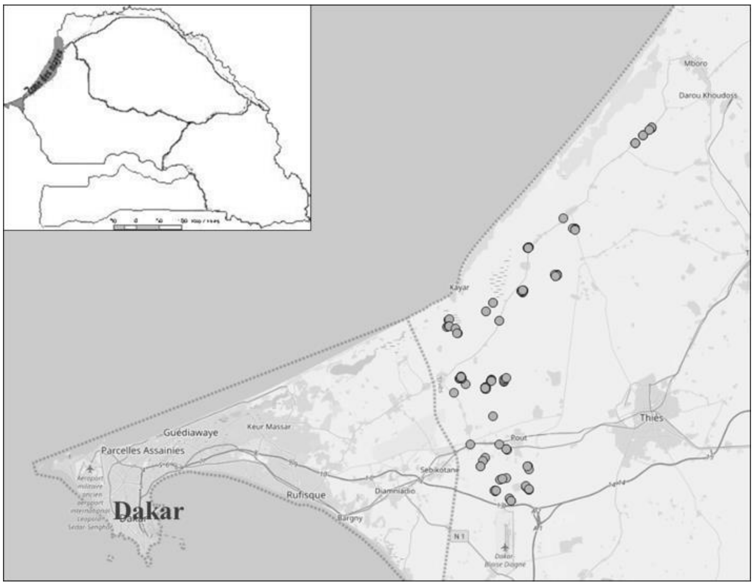


Figure 2. Location of the study zone in Senegal (source: author)

About 30 qualitative interviews were conducted in the study zone of the Niayes prior to the quantitative data collection. They allowed to characterize the processes of labor allocation within the activity system, especially on-farm, and to compare technical itineraries between organic and non-organic farmers.

Quantitative data were collected from 165 households practicing gardening across the Niayes area in Senegal in November 2019. Two federations promoting agroecology were identified, the Federation des Agro-Pasteurs de Diender (FAPD) and the Federation Woobin. 54 farmers belonging to the FENAB – either certified organic or in transition – and from these federations were included in the survey as proxy for most agroecological farms. The sample also included farms recruiting wage workers, either for daily tasks or for a yearly contract.

Table 1. Sample description

	Total	*Organic farmers*	*Non-organic farmers*
Size of households	12.54	12.69	12.48
Number family worker on farm	4.26	3.94	4.41
Number of activites off farm	2.16	2.11	2.19
Off farm revenue (FCFA)	934 447	824 706	987 835
Surface owned (ha)	3.08	2.47	3.38
Cultivated area (%)	73.70	76.38	72.4
Number of animals	7.26	8.09	6.86
Farm revenue (FCFA)	2 486 898	1 337 434	3 046 097

The sample construction aimed at gathering households with diverse farming systems to allow the comparison between agroecological levels. Thus, the chosen households are representative of the diversity of the zone but, overall, not of the actual distribution within the Niayes, as organic farmers are over-represented on purpose in our sample.

Within the interviewed households, all family members' activities on and off-farm over the last 12 months were recorded. The time spent in off-farm activities or migration was entered for each month of the year and the type of participation on the family farm. For this latter, members of the households were either considered full-time workers, weekly or punctual workers and for each category, a weekly or monthly workload was defined. External contribution to peak farm work was also considered. For different tasks, such as weeding or harvesting, households use labor exchange or daily wage workers. Thus, the corresponding amount of labor was estimated from the number of workers and hours per task. A specific set of questions regarding the agroecological practices of the farms and their economic results were asked.

2.3 Analysis conducted

Hierarchical Clustering on Principal Components to build agroecology levels

To go beyond the simple organic/conventional comparison, we want to identify different levels of agroecology within the farms interviewed. This process is complex as agroecology is a multi-dimensional concept defined on principles rather than precise delimitations. Hence, research is still discussing the elaboration of a methodology to specify what agroecology is in the field and what is not. Recent contributions have proposed different methods to identify and evaluate agroecological systems (FAO 2019, Levard et al. 2019). However, the timing of these publications and our specific focus on work prevented us from integrating these latter developments into our methodology. Thus, data available in our sample revolves more around agricultural practices aspects of agroecology rather than its socio-economics dimensions. This limitation is also due to the local meaning and implementation of the concept in the study zone, which is understood mostly as production aspects of agriculture (Boillat and Bottazzi 2020).

A Hierarchical Clustering on Principal Components (HCPC) is used to incorporate agroecology's multiple dimensions and distinguish agroecological levels between farms. The objective is to characterize sets of practices implemented in specific farms that would distinguish groups of farms with particular levels of agroecology. This approach roots in the importance of context in agroecology to identify local contrasts in implementation. There is no ambition to generalize the types identified; the aim is solely to develop a scale to compare the groups of farms.

First, we conducted multiple correspondence analyses (MCA) on a data subset of farming practices variables exclusively, excluding the rest of the households' economic data. Fifty-three variables were collected regarding the agricultural practices of the farms and their linkages within the food system (self-sufficiency, production destination, etc.). After several tests, twenty-two variables were selected as discriminating enough and conveying the necessary information. They are categorical variables on chemical inputs, organic matter management, fallow, plowing practices, diversity in vegetal and animal production, crop rotation, integration with livestock, and food autonomy (presented in results section, Table 1). The observation distribution on the MCA's dimensions allows for identifying irregular patterns, displaying gradient-like shapes rather than definite clusters. The low cluster tendency of the data leads us to adopt a clustering approach as a data reduction means rather than for archetypes identification. Therefore, the formation of the clusters corresponds to a data partition based on many practices with no generalization purpose.

Secondly, the implementation of hierarchical clustering on principal components (HCPC) allowed the distinction of five clusters describing farming systems (FS) (

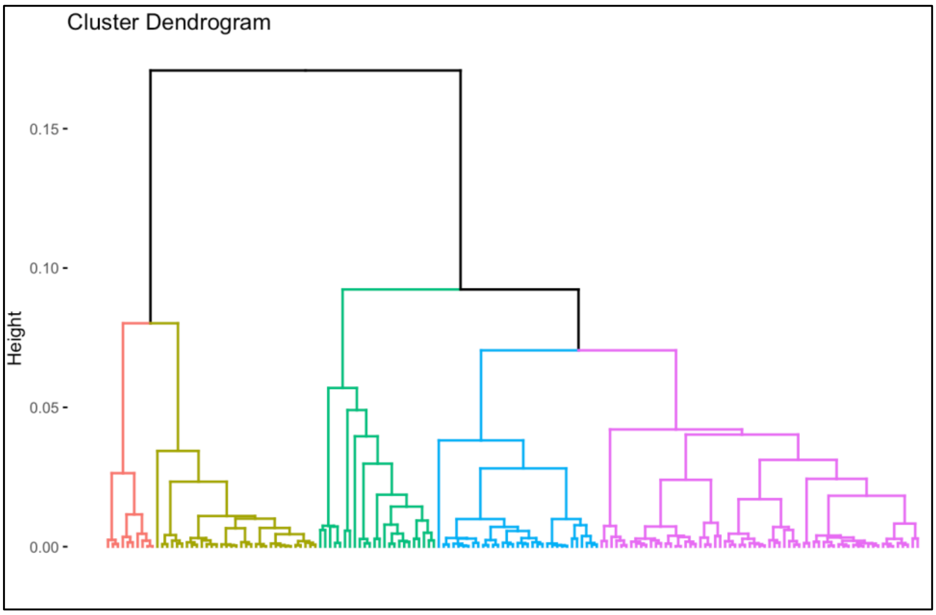


Figure 3). The first sixteen dimensions of the MCA were used for the HCPC to account for 70% of the explained variance of the data. As the clustering tendency of our data is limited, our choice of cluster number is based on the objective of having enough granularity in agroecological levels and the relevance of the clusters obtained regarding fieldwork observation. The five obtained clusters appear meaningful and consistent with field observation.

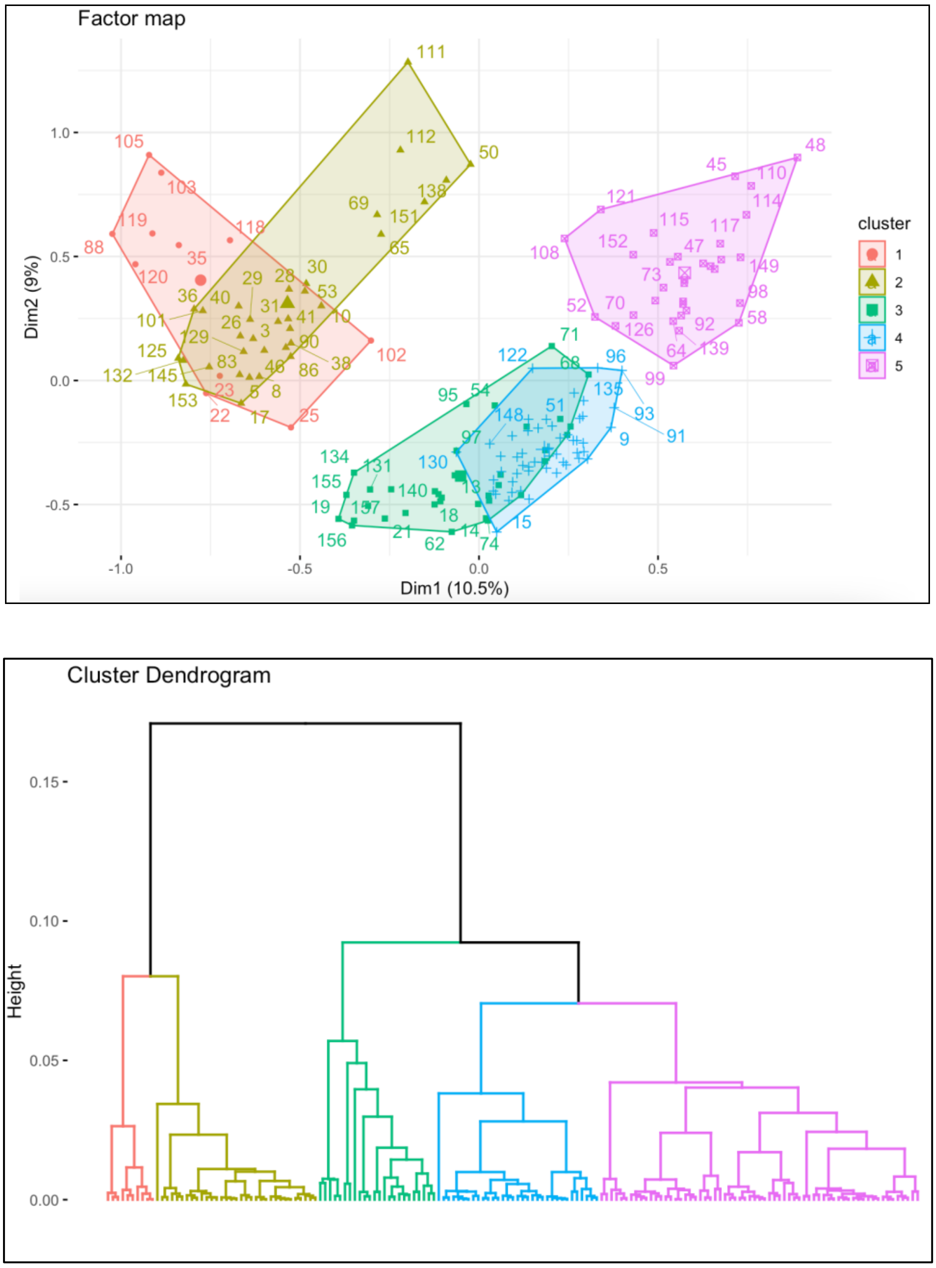


Figure 3. Results of the HCPC

To rank farm groups in terms of agroecology, we build an agroecological score per cluster. We count the agroecological modalities among the modalities statistically characterizing the clusters for each group. Our observations are thus distributed across five groups of different AE levels which can be compared. This modality scoring is not perfect as it involves certain arbitrary distinctions, yet it allows a relevant differentiation of our clusters.

Statistical tests on employment indicators to compare AE levels

After distinguishing five groups regarding agroecology, statistical tests were performed using R to determine significant differences between these groups regarding employment and work indicators. Kruskal-Wallis tests were used to compare the means of the different groups and Smirnov tests to compare their dispersion. Twenty variables regarding the work on the farm, family, and wage, in numbers of workers and hours per hectare per year, are compared, including the work remuneration, calculated from the farm revenue, and the household members' off-farm activities and migrations.

Some chi-square tests were also conducted to better characterize the farming systems and understand their characteristics' effect on work organization.

3 Results

3.1 Tasks comparison between agroecological levels

The agroecological levels built from the HCPC rely on farming practices with direct implications regarding workloads. Our field observations and the literature provide insights regarding these practices' labor requirements. We found a low diversity of agroecological practices within the farms, confirmed by the literature on organic farming in the Niayes area (Kettela 2016; de Bon et al. 2019); even though the interviewed farmers were recommended by the federations, which would make them "good performers". Thus, according to Hill and MacRae's (1996) conceptual framework, the organic farmers of the area seem to be in the "substitution" phase, with mainly substitution of the chemical fertilizer by manure and of the pesticides by organic preparations (made from plants with repellent powers). No reconception of agricultural systems was observed. Similar observations are made by Dugué et al. (2017) on the same federations in the Niayes. Hence, the most agroecological levels studied here do not represent the full expression of agroecology's multiple dimensions.

Table 1. Description of the farming systems based on their modalities

	Cluster 1 (11)	Cluster 2 (33)	Cluster 3 (36)	Cluster 4 (52)	Cluster 5 (32)
Inputs					
purchased seeds	0			1	
	1.48E-11[a]			*1.19E-02*	
chemical fertilizer use				1	0
				3.77E-07	*3.95E-10*
chemical pesticide use				1	0
				4.12E-05	*6.95E-11*
organic pesticide preparation			0	0	1
			6.03E-03	*1.62E-07*	*3.13E-17*
organic pesticide use			0	0	1
			6.84E-03	*6.44E-09*	*1.75E-21*
Soil management					
ploughing	0				
	6.43E-08				
fallow			1		0
			9.14E-10		*1.20E-02*
manure use	0		0	1	1
	1.50E-02		*6.53E-06*	*3.96E-04*	*2.78E-03*
compost			0	0	1
			1.95E-03	*1.88E-04*	*1.21E-06*
crop rotation	0		1	1	
	3.45E-12		*2.70E-02*	*3.33E-03*	
Livestock integration					
crop - livestock linkages	0	0	0	1	1
	3.24E-04	*1.54E-17*	*4.70E-02*	*3.95E-13*	*2.20E-08*
livestock feeding location	0	0	1	3	3
	5.32E-03	*3.33E-28*	*6.27E-08*	*2.62E-03*	*1.84E-02*
livestock feeding type	0	0	2	1	1
	5.32E-03	*3.33E-28*	*4.65E-21*	*3.59E-17*	*4.48E-05*
Diversity					
number of crops	1				8
	1.84E-02				*6.74E-03*
number of production type	1		1	2	3
	2.12E-02		*4.70E-02*	*4.86E-02*	*1.65E-02*
crop association	0				
	1.32E-02				
varieties diversity			0		
			3.80E-02		
ecological regulation space			0	1	1
			6.70E-08	*7.09E-03*	
tree planting on farm			0	1	
			2.94E-04	*1.73E-02*	
number livestock species	0	0	1	2	3,4,5
	5.32E-03	*3.33E-28*	*6.33E-06*	*6.36E-07*	*6.74E-03*
Food system					
farm self-consumption	0	3	2		3
	3.58E-04	*2.33E-03*	*1.04E-04*		*1.48E-02*
Number of AE modalities	2	1	5	8	14
Agroecological Ranking (1 best/ 5 worst)	FS4	FS5	FS3	FS2	FS1

[a] p-value of v-test for this modality representation in the cluster
Red cells correspond to conventional practices and green cells to agroecological practices

The combination of practices highlighted by the clustering and the qualitative interviews conducted in the field also allows for interpreting the clusters created in terms of productive orientation (see Table 1). Chi-square tests allowed to characterize clusters' specificities regarding production types. Thus, besides cluster 1 which do not display gardening characteristics, all farming systems are gardening ones with different degrees of diversity. Cluster 1 is characterized by a specialization in arboriculture, explaining the significance of no ploughing and no improved seeds for this cluster, as all gardening in the area is conducted on ploughed soil and mostly with purchased seeds. Cluster 5 (FS1) and cluster 4 (FS2) are the most diverse farming systems, particularly in their livestock integration. Cluster 5 organic pesticides use and chemical pesticides non-use connect it with organic farming. Cluster 4 appears to be conventional as it uses chemical inputs. However, it also displays a certain level of diversity with its association with breeding and the use of manure for fertilization. Clusters 3 (FS3) and 2 (FS5) present fewer clear features on the input aspect. Yet, the zone is dominated by very conventional forms of farming which would suggest that by default farms tend to use chemical inputs. The differentiation across clusters appears primarily related to farm diversity.

Regarding labor requirements, those results bring forward three aspects likely to affect differently farms' workloads across farming systems:

(a) *The preparation of the substitute for chemical inputs.* Conventional farmers can purchase their inputs directly, whereas organic farmers must prepare them most of the time. Organic pesticides can sometimes be bought but they can also be prepared from local plants. Compost preparation is a particularly labor-intensive process. Therefore, this preparation time is a net work increase.

(b) *Farm diversity*. It is a feature that appears to differentiate most farming systems. It takes place at various scales, in terms of number of productions, number of crops, and number of varieties and species. When comparing breeding between agroecological levels, we find that more agroecological breeding is significantly more diverse with a higher average number of species. By nature, managing diversity requires time to adapt practices for different categories and more reflection on management.

(c) *Livestock integration*. It is a distinctive feature of the two highest agroecological levels. Both handling manure and increased species diversity involve more work. Using manure from its own farm requires time to collect and store it.

Additional tasks performed at higher agroecological levels should involve more work for the farmers in the Niayes area. However, multiple aspects of technical management such as task frequency or surface cultivated could mitigate such task increase effects on total workload. We want to evaluate the effects of these extra tasks on the farms working hours and the number of workers.

3.2 Comparison of the employment indicators between agroecological levels

We first compare the farming systems using Kruskal-Wallis tests on employment and work variables. After this test, Dunn tests are conducted to identify two by two significant mean differences between groups. Twenty variables on farm labor, off-farm, labor type, and gender-disaggregated work hours are tested (see results in Table 2). Eighteen of these variables show no significant differences, indicating similar levels across farming systems of family workers on the farms, of hours worked by ha for different types of labor (daily, weekly, punctual), and off-farm activities. Significant differences between farming systems are only found for the number of daily salaried workers per hectare and the number of hours worked by women in the year per hectare. The dispersion of these variables is presented in **Erreur ! Source du renvoi introuvable.** and **Erreur ! Source du renvoi introuvable.** to identify a relation with the agroecological levels.

Table 2. Kruskal-Wallis tests on work variables

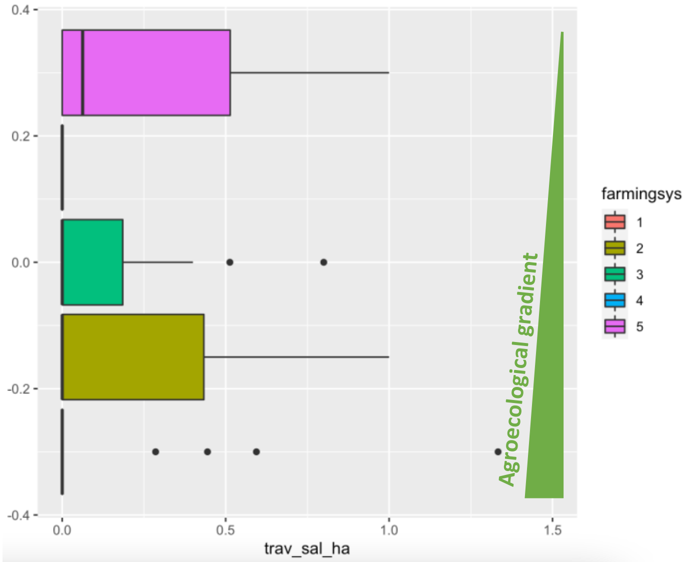
	FS 1 (32)	FS 2 (52)	FS 3 (36)	FS 4 (11)	FS 5 (33)	Kruskal-Wallis p-value	Dunn test
Number of workers per ha							
Daily family workers per ha	1.066	1.067	1.104	2.044	1.540	0.125	
Daily wage workers per ha	0.091	0.455	0.108	0.000	0.350	2.37e-04***	1-2**, 1-5*, 2-4*, 4-5*
Total daily workers by ha	1.158	1.523	1.212	2.044	1.890	0.110	
Weekly family workers by ha	0.485	0.887	0.557	1.516	0.866	0.962	
Punctual family workers by ha	0.590	0.535	0.345	2.126	0.580	0.0497*	n.s.[a]
Hours worked per ha							
Hours worked of daily family worker per ha per year	2314.7	2277.2	2248.6	2858.3	3655.5	0.428	
Hours worked of punctual family worker per ha per year	184.9	217.0	107.5	541.1	103.4	0.0524	
Hours worked of weekly family worker per ha per year	339.5	521.2	350.7	509.9	459.6	0.993	
Total hours worked by family workers per ha per year	2839.1	3015.5	2706.9	3909.4	4218.6	0.327	
Total hours worked by external labor for peak work per year	68.254	54.44	54.49	24.00	87.53	0.0476*	n.s.
Work value							
Value created per family worker [b]	362260.4	491839.1	380488.4	35456.6	255320.4	0.198	
Value created per hour of family work [c]	442.65	332.22	263.63	48.98	174.47	0.521	
Value added by number of total workers (family+wage) by ha	350322.5	337957.6	243068.6	153511.6	266125.0	0.517	
Irrigation							
Hours spent for irrigation per ha	1224.0	1316.9	1019.3	513.9	3091.5	0.119	
Hours non irrigating per ha	1998.4	2490.5	2649.1	2436.0	3375.2	0.331	
Gender-disaggregated							
Hours worked by family women per ha	1101.9	458.2	249.5	651.7	938.1	9.4e-04***	1-3*, 1-2**
Hours worked by family men per ha	1737.1	2529.2	2400.4	3257.7	3214.3	0.339	
Off-farm work							
Number of off-farm activities of the household	2.586	2.404	2.000	2.111	1.696	0.265	
Total remuneration of the off-farm activities	1083586.6	957323	1006314.8	1097780.9	631734.2	0.128	
Hours worked off farm by family	3446.0	3412.2	2832.4	3724.0	2253.4	0.062	

[a] *non-significant*

[b] *added value of the farm divided by family workers*

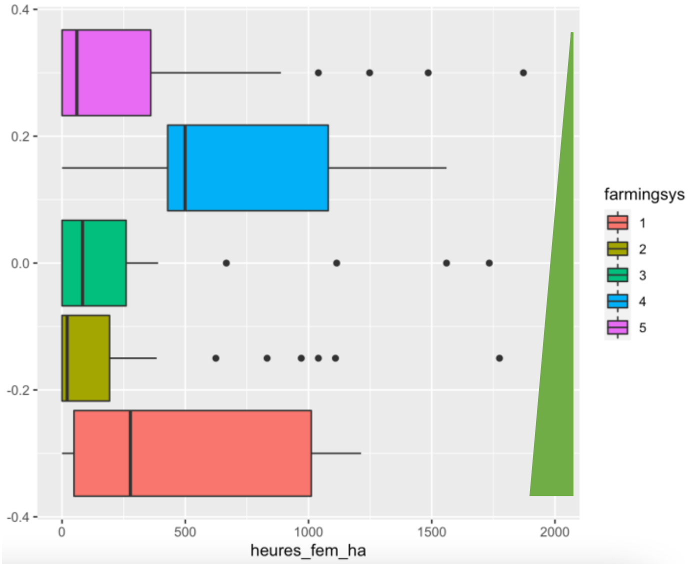
[c] *added value of the farm divided by hours worked by family workers*

The dispersion graph displays lower levels of wage workers per ha for FS1 and FS4, compared to the other groups (Figure 5), which are significant according to the Kruskal-Wallis tests. On the other hand, those two clusters also present higher levels of hours worked by women per ha (Figure 6). Regarding women's labor, the Kruskal-Wallis tests indicate the significance of these differences only for FS1. Yet, these differences in levels of specific labor are not reflected in the total amount of work total or per hectare. A first hypothesis to explain this pattern would be that women's labor is used as a substitute for wage workers in these groups.



Significant: 1-2**, 1-5*, 2-4*, 4-5*

Figure 4. Number of daily wage workers per ha by farming systems



Significant: 1-3, 1-2***

Figure 5. Hours worked by women per ha by farming systems

We then compare the dispersion of the same employment variables across farming systems by performing two samples Smirnov tests. Eleven variables show significant differences in dispersion between specific farming systems. However, most of these significant results are due to the FS4 which displays specific behavior due to its arboriculture nature, and possibly to its lower number of observations. It has a significantly lower and smaller range of daily workers per ha values, as well as narrower and higher distribution for the off-farm activities variables, and a narrower and higher range for work outside of irrigation. The dispersion tests strengthen the evidence on wage workers and women's labor for the FS1 and FS4, with significant differences for both with Smirnov tests. These two farming systems differentiates from others by their singular nature: FS1 is organic and most agroecological and FS4 is specialized in arboriculture.

In the two test categories used, no pattern in work quantity explicitly related to the different agroecological levels appears. Our qualitative interviews in the area provided elements regarding the importance of the effects of irrigation on the workload. So, we formulated the hypothesis that the differences observed in the number of daily workers per hectare are mainly influenced by levels of mechanization of irrigation, thus hindering the possibility of grasping an agroecology effect. Irrigation equipment significantly impacts farmers' daily workload, with huge variations from manual water recuperation by buckets or motorized pumps. Therefore, we looked at the irrigation equipment of the farming systems by performing chi-square tests on the categorical variables for motorized pumps and irrigation devices comparing the farming systems. At first, the results were in line with our hypothesis showing significant differences in equipment between FS. Still, we find no significant difference when looking further into irrigation working time and working time outside irrigation (Table 2). Thus, irrigation equipment cannot be why we do not observe the effect of agroecology on work in our data.

3.3 Discussion

Our main finding is the significantly higher number of hours worked by women per ha in the most agroecological farming system (FS1), associated with significantly lower numbers of wage workers. The fact that this larger quantity of women's hours is not reflected in the total hours worked suggests a substitution with wage labor. Several mechanisms could explain women's extra hours and the substitution of wage workers. Specific tasks nature could require frequent but low numbers of work hours, for which hiring a full-time wage worker would not be cost-effective. Another explanation could be a voluntary broader integration of women on more agroecological farms, based on socio-economic dimensions such as women empowerment. Or it is a purely economic measure as women's hours are most of the time not remunerated contrarily to wage labor. However, intra-family payments for farm work have been observed multiple times in the zone. This FS1 pattern similarity with FS4 is puzzling as FS4 presents multiple specificities described in the previous section. It is to be noted that women's hours are significantly higher for FS1 than FS4. The arboriculture nature of FS4 could then justify the absence of need for full-time wage workers (daily workers per ha is the lowest for this group) and the mobilization of women labor intensively for fruit trees harvesting, as this FS displays much higher levels of punctual family work per ha (where FS1 is stable). FS1 is the only gardening system presenting pattern, thus, pointing to a possible link of this pattern with its agroecological nature.

Our results show no difference in total work quantities across farming systems related to agroecological levels, meaning that no job creation is observed. However, our qualitative interviews indicated that there should be at least additional work in more agroecological farming; the diversity of the farming systems in itself involves more management. Binta Ba and Barbier (2015) did find differences in working time between organic and non-organic when collecting data at the field scale in the Niayes. Hence, we suppose that this extra work is not visible in our results because: (1) it is very small and has no impact on the number of workers; (2) the additional tasks might be managed by the farming household flexibility. The recent literature suggests that the new tasks related to agroecology might be supported by farmers' overtime or other family members such as spouses or children (Montt and Luu 2020, Pereira Fontes 2020). For instance, in the Niayes, breeding animals are often kept within the family house; thus, women staying at home might be the ones taking care of them and supporting the extra work related to the increase in breeding diversity, which is consistent with our results on women hours increase. The preparation of chemical inputs substitute might also be done between other tasks, hence not significantly increasing the overall working time. These hypotheses need to be verified by further data collection.

Moreover, we did not find significant differences in revenue between farming systems. The NGO Enda Pronat has set up a commercialization network in the area to provide better prices for the farmers in agroecology. However, it faces several logistical challenges and cannot absorb a large share of the production of organic farmers. The issue of the agroecological production valuation is critical for a decent remuneration for any extra work. Higher revenue might allow farmers to have an additional person working full time on the farm, either family or wage worker, corresponding to job creation.

The farming systems comparison may present the limitation of not disentangling their different characteristics' specific effects on work, among which agroecology's. However, we argue that these characteristics are fundamentally intertwined. Agroecological practices are anchored in family farms' work organization, socio-economic composition, and production mixes. As such, their effect on work should not be considered "other things being equal" but understood within a given system in a specific context. It is through the accumulation of evidence across contexts and contrasted systems that a broader understanding of agroecology's job creation potential can be built.

Conclusion

From the analysis of our data collected in the Niayes area of Senegal, we find no evidence of higher labor requirements related to agroecological practices. Even though our qualitative interviews and task comparison highlight additional tasks for farmers in agroecology, it does not translate into job creation. However, the most agroecological system observed displays a significantly higher number of working hours by women per hectare and a lower number of wage workers per hectare, suggesting a potential substitution between these two labor types. As this result is specific to the most agroecological gardening system that we observe, it is likely to be related to the agroecological practices put in place on those farms. Further research should be undergone to understand the processes at play.

These results are context-specific but indicate that the opportunity for job creation in agroecology is not straightforward. As observed in other contexts, farm employment most likely also depends on the farming systems' characteristics and local labor mobilization institutions (Darpeix, Bignebat, and Perrier-Cornet 2014). In the Niayes, farmers declare hiring workers very easily; the zone is known for attracting migrant workers from other regions of Senegal (Ba, Bourgoin, and Diop 2018). Massive youth unemployment in Senegal facilitates labor availability for agriculture in certain areas. However the question of the sector's attractiveness is still critical elsewhere (Sumberg et al. 2014). Therefore, the drudgery of work and decent working conditions should also be considered when discussing job creation for structural transformation paths.

On the other hand, the absence of evidence of a total increase in workload for more agroecological systems can also be seen as an opportunity. As an increase in workload is often presented as a limit to agroecology's adoption (Dugué 2014), labor requirements similar to conventional farming would facilitate farmers' transition.

As underlined earlier, our data and method face some limits. First, agroecology observed in our study zone is mainly at a substitution stage which does not allow us to measure the full benefits of specific systemic functioning of agroecology. One significant difference in work is usually the use of herbicide versus manual weeding, whereas, in our zone, both conventional and organic farmers were doing manual weeding. The effects of agroecology on gardening, an already labor-intensive production, might be smaller than on other types of productions, such as rain-fed crops. To fully grasp subtle differences in work that might take place between agroecological and conventional farming, a data collection at the task and field level would allow going into more detail. Lastly, as agroecology and the labor market are heavily context-dependent, multiple similar studies in different contexts across SSA should be necessary to validate a trend in job creation that could provide insight regarding desirable structural transformation pathways.

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