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# Work organization as a barrier to crop–livestock integration practices: a case study in Guadeloupe

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## Abstract

Crop–livestock integration exploits the synergies between cropping and livestock systems, mainly by using animal excreta as an organic crop fertilizer or using crop products as animal feed. From an environmental and economic point of view, crop–livestock integration is thought to increase system autonomy and resilience. However, little research has addressed its social impact and particularly the relationship between crop–livestock integration and work organization although, like most agroecological practices, crop–livestock integration was considered time- and labor-intensive. Here we used quantitative indicators based on the “Qualification and Evaluation of Work” method coupled with qualitative interviews with farmers to understand how implementation of crop–livestock integration practices is affected by work characteristics (perception, organization, duration, and arduousness). This framework was implemented on 14 farms selected from a typology of mixed crop–livestock systems in Guadeloupe (French West Indies), where high labor costs heighten the tension between work organization and agroecological practices. Our results show that three patterns of crop–livestock integration shaped work organization: family farms with strong crop–livestock integration (Pattern 1, n=6 farms), farms with moderate crop–livestock integration (Pattern 2, n=5 farms), and intensive productivity-driven farms (Pattern 3, n=3 farms). We also show for the first time that farmer perceptions of work, especially with animals, influences level of implementation of crop–livestock integration practices. In Pattern 1, work with livestock is done by the farmers themselves or by skilled and trusted persons from their inner circle. In Pattern 3, livestock was considered a source of on-farm income, and work with livestock, including crop–livestock integration practices, is readily delegated to employees or volunteers. Whatever the pattern, the time burden of collecting crop-products and excreta was cited as a primary barrier to further implementation. Actionable opportunities for further implementation of these patterns of crop–livestock integration practices are discussed.

**Keywords** Work organization · Integrated crop–livestock system · Family labor · Agroecology

## 1 Introduction

Intensive farming was promoted as part of the postwar effort to feed the global population. Now called “conventional agriculture,” it transformed farm structures, driving them to decouple crop and livestock production and specialize (Garrett et al. 2020), but it has also shown limits in terms of environmental impacts (soil leaching and erosion, decrease in soil nutrient content, biodiversity loss, groundwater pollution, and greenhouse gas emissions). Agroecology, which has been defined as a movement, a scientific discipline, and a set of practices, is now emerging as a solution to increase output and meet growing demand for agricultural products while decreasing the negative externalities of conventional agriculture by optimizing the use of local resource, minimizing fossil energy requirements, and more.

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Agroecology, as a set of practices, promotes the adoption of new and more sustainable techniques in farming systems (Wezel et al. 2014). However, these new practices affect farmers' working conditions (Aubron et al. 2016; Bendahan et al. 2018; Duval et al. 2021), as they can compete with other on-farm interventions or demand an initial period of learning that can quickly discourage farmers (Duval et al. 2021). Working conditions influence the ways in which farmers adopt and implement agroecological practices and engage in the agroecological transition.

Among the diverse array of agroecological practices, crop–livestock integration (CLI) is highlighted as a valuable strategy due to its benefits for sustainable food production, livelihood improvement, and efficiency (improvement of resource use). CLI exploits the synergies between cropping and livestock systems, enabling mixed crop–livestock systems (MCLS) to connect environmental, economic, and social objectives such as climate change mitigation, greater economic efficiency and lower costs by minimizing the need for external inputs (Herrero et al. 2010; Ryschawy et al. 2012; Stark et al. 2016). CLI is a set of practices that mainly revolve around using crop products and by-products to feed livestock, using animal excreta to fertilize crops, and using livestock as draught power. Worldwide, there is broad spatial and/or temporal variety in the ways that CLI practices are employed (Fig. 1), including synchronized integration by the use of dual-purpose crops, integration by rotation, cut-and-carry systems, or between-farm integration (Bell and Moore 2012). This variety of CLI practices generates different types of MCLS that fall into a

continuum from “segregated MCLS” with a low level of crop–livestock interaction and a high reliance on external inputs to centuries-old “traditional MCLS” which have little or no reliance on external resource inputs (Garrett et al. 2020). In tropical regions, MCLS are still rooted in the landscape, mainly in a traditional form on smallholder farms where they provide households with both food and income (Herrero et al. 2010), whereas in temperate areas, the general trend is still toward a decoupling of crop and livestock systems, leading to segregated MCLS (Ryschawy et al. 2012; Garrett et al. 2020).

At the farm level, several factors can affect the implementation of CLI practices, including amount of subsidies, decrease in input costs, level of farmer education, or lack of professional organizations (Fanchone et al. 2020). MCLS are widely perceived as having lower profitability and higher (and more skilled) labor requirements and upfront costs than specialized systems (Cortner et al. 2019). Quantitative (duration and frequency) and qualitative (arduousness and skill) features of work can limit CLI implementation (Ryschawy et al. 2012; Cortner et al. 2019), especially due to the presence of animals. Livestock management involves a very different pattern of work compared to crop activities: livestock work is done on a daily basis, and many tasks are not postponable (Hostiou and Dedieu 2012), which thus requires more labor and more skilled labor with person experienced with animals than extensive or completely mechanized crop systems (Cortner et al. 2019; Garrett et al. 2020). Efforts to promote the development of CLI also need to account for, in addition to the economic rationality, a number of subjective factors

**Fig. 1** Example of organic fertilization (including animal excreta) in banana plantation in Guadeloupe. This practice is mainly manual in small family farm with the excreta put directly in the planting hole (top picture, Credit: Madly Moutoussamy, INRAE). Mechanized material available (here in large banana farm) is not affordable/ adapted for small farms (bottom picture, Credit: Audrey Fanchone, INRAE).



(Fiorelli et al. 2012) such as animal and farmer welfare, contact with nature, or identity, which Coquil et al. (2018) called “farmer singularities”.

Most of the research on MCLS has focused on the economic and environmental impacts of CLI at both farm level (Sneessens et al. 2016; Stark et al. 2016) and territorial level (Moraine et al. 2016). Few studies have addressed the issue of labor in the management of crop–livestock operations, and none used a systemic analysis of work organization (Duval et al. 2021). Moreover, methods developed to address work organization by modeling farm-level crop and livestock organization have failed to account for farmers’ needs and knowledge in their analysis of how crop–livestock practices are actually implemented (Madelrioux and Dedieu 2008; Hostiou and Dedieu 2012). Only Malanski et al. (2019) included subjective indicators in their analytical framework.

To address the gaps, the objective of this study was to identify how the implementation of CLI practices is affected by farm-level work organization, and to identify work organization-related barriers and opportunities for accelerating the development of CLI practices.

We begin by presenting different patterns of how CLI shapes work organization (duration, arduousness), then go on to describe perceptions of work with animals expressed by farmers and the impact of these perceptions on CLI practices. We then discuss the main barriers and opportunities proposed by farmers for developing CLI.

## 2 Materials and methods

### 2.1 Study area

This study was carried out in Guadeloupe, a French insular archipelago (1,434 km<sup>2</sup>) in the Caribbean Sea (latitude 16°13' North, longitude 61°34' West). Guadeloupe encompasses a broad diversity of farming systems engaged at various stages in the agroecological transition process (Fanchone et al. 2020). Like other Caribbean islands, Guadeloupe plays host to strong environmental and socioeconomic mutations operating at small spatial scales (insularity, coexistence of several agricultural models) and temporal scales (speed of evolution of phenomena). The significant access to capital and the high cost of labor because of membership of France and the European Union (access to subsidies, submission to labor law of industrialized countries) make Guadeloupe a good laboratory to study the tension between work organization and implementation of agroecological practices.

Guadeloupian agriculture is mainly based on small MCLS farms with an average size of 4.1 ha, which represent 80% of the farms in the study area (Stark et al. 2016). Much of Guadeloupe’s agricultural land cover (31,400 ha) is sugarcane and banana, two highly subsidized export crops that represent

45% and 8% of local arable farmland, respectively (Fanchone et al. 2020). Pasture and fallow currently account for close to half of the arable land of the island. Food crops (vegetables, tubers, and plantain), ruminants (mainly cattle, goats, and sheep) and small livestock (poultry, pork, and rabbit), which are less subsidized and oriented to the local market, are often produced along with one or both of the two major exports crops. Farms also include market gardening, orchards, or tuber and fruit outputs. Products destined for the local market do not cover local demand, and so the island is exposed to strong dependence on external sources. The agricultural trade balance shows a large deficit, as 80% of food comes from imports (Fanchone et al. 2020). Moreover, both crop and livestock and activities are heavily reliant on increasingly expensive imports of feed concentrates and mineral fertilizers.

### 2.2 Farm sampling

Sampling was based on farms that already implement CLI, as their skill and feedback on CLI practices can benefit other farmers in their learning process (Coquil et al. 2018; Delecourt et al. 2019). We thus used the MCLS typology given by Stark et al. (2016), which was developed on a set of 111 MCLS farms representative of the diversity of farming systems in Guadeloupe, to build the sample of farms interviewed here. In this typology, farms were discriminated into three types of MCLS based on level of production factors and diversity of production: (i) small labor-intensive farms (SLI), (ii) medium-sized extensive farms (ME), and (iii) medium-sized capital-intensive farms (MCI). ME farms have a more extensive combination of outputs than SLI and MCI farms. SLI farms have a lower agricultural area and less access to capital than ME and MCI farms (Stark et al. 2016). Fifteen livestock farmers (5 per type) were selected on the grounds that they 1) were representative of the different types in the typology (for products and production factors), 2) cover the diversity of agricultural zones in Guadeloupe, and 3) had not experienced any substantial change in farm structure and function since the exploratory survey by Stark et al. (2016).

Note that one of the farmers (MCI1) died during the data collection process, which was not therefore completed. The analysis thus covers 14 farms (5 SLI, 5 ME, and 4 MCI). Average farm size was 6.4, 16.7, and 12.9 ha for SLI, ME, and MCI, respectively (Table 1). Most farms produced market-garden crops (n=12), followed by sugarcane (n=11), pasture (n=11), food crops (n=8), and arboriculture (n=8). Given the purpose of the study, only farms that also produced livestock were chosen. Ruminants (cattle, goat, sheep, or donkey) were reared on 11 of the farms, and monogastrics (pigs, poultry, and rabbit) were reared on 12 of the farms. Most of the farms (n=11) reared more than one animal species, with a maximum of four different animal species on the same farm (SLI2 and SLI5).

**Table 1** Farm characteristics (area and size of the crops and herds) of the 14 mixed farms. <sup>1</sup> TLU = Tropical livestock unit: 1 cattle = 0.8 TLU, 1 pig = 0.2 TLU, 1 Donkey = 0.50 TLU, Sheep = 0.10 TLU, Goat = 0.08 TLU, and 1 rabbit or 1 poultry = 0.01 TLU.

Item	SLI1	SLI2	SLI3	SLI4	SLI5	ME1	ME2	ME3	ME4	ME5	MCI2	MCI3	MCI4	MCI5
Area (ha)	10.0	7.0	3.0	8.2	4.0	17.6	20.0	19.0	15.0	12.0	12.0	17.0	11.0	11.5
Crops area (ha)														
Sugarcane	7.0	1.5	-	5.0	-	7.6	6.0	12.0	8.0	6.5	-	6.2	8.0	7.0
Market gardening	0.4	0.5	-	0.2	0.3	0.25	3.0	0.5	4.0	0.2	9.0	8.0	-	1.0
Food crops	0.4	0.5	-	-	-	1.5	4.0	0.5	0.8	-	-	1.0	-	2.0
Arboriculture	0.2	-	3.0	-	0.3	0.1	0.4	-	0.5	-	2.0	1.0	-	-
Pasture	2.0	3.5	-	3.0	3.0	6.2	3.0	6.0	0.5	3.0	1.0	-	3.0	-
Livestock														
Ruminants (TLU <sup>1</sup> )	4.9	2.4	-	15.4	5.6	14.0	29.4	21.7	2	14	17.6	2.8	-	-
Monogastrics (TLU)	-	1.23	0.4	0.2	18.2	6.1	0.92	1.2	-	1.2	14.0	8.7	44.0	11.4
Herd (animal number)	7	40	20	23	173	58	58	37	6	26	70	811	220	570
Number of animal species	1	4	1	2	4	3	3	2	2	2	2	3	1	2

### 2.3 Data collection

We used the conceptual framework of livestock farming systems (Gibon et al. 1999), which considers the farmer as driver of the system and work organizer (Dedieu and Servièrè 2012; Courmut et al. 2018), to perform a systemic analysis of the farms in our sample. Data were collected during two interviews conducted with farmers during a visit of the farm. All the farmers contacted responded to the surveys. Data were collected by the investigators on a written questionnaire, and the answers were entered immediately after the interview to avoid loss of data (Table 2).

The aim of the first survey was to collect structural and quantitative data on work organization and agroecological

practices. One interview lasting 90 min to 2 h was carried out on-farm with the farm manager by a student intern. We used the QuaeWork method developed by Hostiou and Dedieu (2012) to assess the on-farm work organization. QuaeWork characterizes and qualifies the work organization based on the interactions between the farm technical system, the workforce, and all on-farm and off-farm activities. It also aims to identify the rationalities underpinning the farm organization. Given the purpose of the study and the burden of implementing the entire method, we did not address all the QuaeWork dimensions of work organization such as flexibility (management of workload peaks) or room for maneuver over time. Here we mainly collected quantitative data on the durations of work tasks related to CLI practices adopted. To

**Table 2** Characteristics of work organization : description of the workforce, work duration (routine work efficiency and time spent performing crop livestock integration practices in the 14 mixed farms). 1 TLU = Tropical livestock unit: 1 cattle = 0.8 TLU, 1 pig = 0.2 TLU, 1

Donkey = 0.50 TLU, Sheep = 0.10 TLU, Goat = 0.08 TLU, and 1 rabbit or 1 poultry = 0.01 TLU; 2 O = Occasionally, R = Regularly, S = Seasonally; 3 F = Family, E = Employee, V = Volunteering.

Item	SLI1	SLI2	SLI3	SLI4	SLI5	ME1	ME2	ME3	ME4	ME5	MCI2	MCI3	MCI4	MCI5
Workforce														
Permanent workers (type)														
Farmer and family (number of workers)	1	1	1	1	1	2	1	1	1	1	1	1	1	1
Hired labor (number of full-time workers)								0.14			1	0.28	0.5	
Seasonal workers (type)														
Family labor (number of workers)	3	3	1	2	4		2			1	1	2	2	1
Family labor (frequency <sup>2</sup> )	S	R+O	O	O	R+O		O			O	O	R	O	R
Volunteering (number of workers)		2		1	1				1	5			1	1
Services providers (frequency)	+	-	-	+	+	+	+	+	+	-	-	-	+	+
Work duration														
Seasonal Work (h/d)	3.6	6.5	2.9	3.7	2.6	9.6	6.2	8.3	13.8	5.7	29.4	11.3	2.5	9.6
Routine Work (h/d)	1.25	1.7	0.3	4.6	5.6	1.83	3.8	1.6	0.8	2.6	3.0	7.1	7.5	0.8
Routine Work efficiency (h/d/TLU)	0.21	0.19	0.50	0.26	0.23	0.04	0.09	0.05	0.15	0.13	0.14	0.27	0.14	0.07
Sharing of work with animals <sup>3</sup>	F	F		F	F	F		E		F	E+F	E+F	E+F+V	V
Use crop products as animal feed (h/year)	3.0	3.6	720.0	41.2	563.7	3.4	344.9	194.3	134.4	328.9	-	262.9	-	-
Use excreta to fertilize crops (h/year)	6.2	16	11	22	20	-	26,8	20,9	4,3	16,3	16,9	14,5	18,4	54,2

address work content (the “what”), QuaeWork method defines two types of tasks according to their rhythm and postponability (Madelrieux and Dedieu 2008). Daily routine work cannot be postponed or concentrated, whereas seasonal work has different degrees of postponability. Daily routine work and seasonal work were quantified in hours per day. Work duration was quantified based on the different categories of in-farm workers (family, volunteers, and hired labor). Family labor refers to persons from farmer’s family circle (dad, mother, partner, son, cousin, ...) whereas, volunteers are friends or other farmers who work in the farm without payment in working exchange system. Hired labor refers to agricultural paid workers. They can be permanent workers (working all year long) or partial workers when they sell their labor skills in several farms. For livestock or crop production, the type of work (daily routine work or seasonal work) was not defined in advance as it depends on each farm’s configuration. The QuaeWork method has been adapted to farms in Guadeloupe as they can encompass up to 20 different production activities (Fanchone et al. 2020). As the farmers would struggle to quantify and qualify all the farm tasks for each production activity (and the interview would take too much time), we used the conceptual model developed by Stark et al. (2016): different species were pooled into compartments based on their agronomic features (crop cycle, species, storage, etc.) rather than accounting for each and every species. Because of their central role in Guadeloupean agriculture, sugarcane and banana are represented as specific compartments. The other four cropping compartments were crops traditionally grown in Guadeloupe, which were pooled according to their production cycle and management practices: tubers (often cultivated on mounds, with a medium-term cycle), market-garden crops (short cycle, often intercropped), fruit (medium-term cycles, specialized), and agroforestry crops (perennial crops). All livestock compartments were addressed in relation to the objectives of the study.

The main works tasks related to livestock compartments (feeding the animals, moving animals from one grazing plot to another, etc.) and harvesting of crop products to feed animals were considered as daily routine work. Other tasks with the crops (soil preparation, crop maintenance, etc.) and livestock (animal cares, harvesting of animal excreta, etc.) were considered as seasonal work.

This first survey also collected data on the CLI practices implemented on the farm (using crop products and by-products as animal feed and using animal excreta to fertilize crops). Farmers were also asked to estimate the time required to collect, transport, and distribute the crop products or spray animal excreta (hours per practice) and the frequency (number per year) of these practices, which served to calculate the annual time required to perform CLI-specific practices (hours/year).

The aim of the second survey was to collect qualitative data focused on how farmers perceived CLI and how they managed CLI in terms of their labor force. Again, one interview lasting 90 minutes to 2 hours was carried out on-farm with the farm manager by a student intern. We used a qualitative interview to better understand farmers’ subjective relationship to their work, their perceptions of CLI practices, and the role of animals within their farm. This second survey, using a semi-directive interview, started by working with the farmer to validate the results of the first interview. The farmers were then asked to explain (i) the tension that emerges from having animals on their farm and performing CLI practices in their work organization, (ii) their motivations for having animals on their farm and performing CLI practices despite this tension, (iii) the main barriers to further development of CLI practices, and to propose (iv) pathways for improvement.

## 2.4 Data analysis

The data were analyzed in three steps.

### 2.4.1 Description and quantification of crop–livestock work

In a first step, an Excel file produced by the QuaeWork method (Hostiou and Dedieu 2012) was used to quantify or describe work organization (workforce, routine and seasonal work times), delegation of work with livestock, and time devoted to implementing CLI practices (using crop products as animal feed, using animal excreta for fertilizer). The number of animals was expressed in tropical livestock units (TLU) to compare different species (1 cattle = 0.8 TLU, 1 pig = 0.2 TLU, 1 donkey = 0.50 TLU, 1 sheep = 0.10 TLU, 1 goat = 0.08 TLU, 1 rabbit or poultry = 0.01 TLU). Data from the second survey was collected using a written questionnaire and completed immediately after the survey in a Word document to faithfully record the themes voiced in the farmers’ verbatim statements.

### 2.4.2 Identification of patterns of farms based on CLI practices and delegation of livestock work

The aim of the second step was to identify patterns of farms that shared common characteristics. To build synthetic variables, we used a method borrowed from “knowledge engineering” (Girard et al. 2008) that consists of building a “series of dichotomic attributes,” which we call “variables” here, defined by extreme situations encountered in the studied cases, and then identifying intermediate situations, which we call “classes” here. Each variable was categorized into classes by opposing the two extreme farms. Classes were built by progressively considering the other farms until no additional separation was necessary. The classes of each variable were then combined into a graphic output to distinguish the forms of

work organization by building a “Bertin matrix” (Bertin 1977) in which each row represents one variable and each column represents one farm. Each cell displays the category for one variable for each farm. A color gradient (white, light green, and dark green) was used to distinguish the classes of each variable, with darker colors indicating more change for the given variable. This graphic representation was used to extend the visual cognition (Bertin 1977). Farms with similar visual profiles were pooled into groups.

Three variables were retained from the first step of data analysis and subsequently used to identify groups of farms. Two of these variables (using crop products to feed animals and using animal excreta to fertilize crops) allowed us to define and characterize the level of CLI and the third variable served to characterize the delegation of work with livestock. In the Bertin analysis, we gave more weight to the use of crop products to feed animals than to the use of animal excreta to fertilize crops. This variable thus became the first contributor to pattern construction. The use of crop products is a daily practice that cannot be aggregated or postponed and thus counts as routine work, whereas use of animal excreta to fertilize crops is easier to postpone and/or aggregate over a given period and consequently counts as seasonal work.

Among the 14 farms studied, 11 used crop products to feed their livestock (Table 3). Four of these 11 farms had to

transport crop products from one site to another on the farm, whereas one farm used crop products from another farm. Ruminants were mainly pasture-fed. As observed by Stark et al. (2016), crop products used as feed were mainly given to pigs (10 farms). Seven farms with pigs used food crops and market-garden products, whereas three farms used sugarcane straw and by-products. Sugarcane was mainly used for ruminants, whereas food-crop and market-garden products were used by two farms with ruminants. Twelve farms used compound animal feed to supplement the animal diet or as their sole feed source. Compound feed as sole feed source was exclusively used for monogastrics (pigs and poultry, or rabbit). Regarding this practice, and in accordance with Stark et al. (2016), we ran Bertin analysis using three classes of crop-product use for animal feed: (A) 100% crop-product feed, (B) both crop products and compound feed, (C) 100% compound feed (Table 4).

Thirteen farms used animal excreta to fertilize crops (Table 3). As reported by Stark et al. (2016), organic fertilization practices mainly involved directly depositing animal excreta in the field (mainly for ruminants, 10 farms) or using excreta to fertilize market-garden and food crops (11 farms). Direct manuring with ruminant excreta only becomes completely virtuous when the farmers practice crop rotation, field grazing of residues, or excreta collect-and-carry (Bell and

**Table 3** Crop-livestock integration practices in the 14 mixed farms in Guadeloupe.

	Animal feeding practices	Organic fertilization practices
SLI1	Pasture, sugarcane straw and by-products, market garden by-products to feed cattle	Cattle excreta fertilize pasture or market garden after harvest
SLI2	Pasture and sugarcane silage to feed cattle, market garden and food crop by-products to feed sheep and poultry; Use of compound animal feed for cattle, sheep and poultry	Cattle excreta fertilize pasture, poultry and sheep excreta fertilize market garden and food crop
SLI3	Crop-by products from orchards to feed rabbits; Use of compound animal feed for rabbits	Rabbit excreta fertilize trees
SLI4	Pasture and sugarcane to feed cattle; Use of compound animal feed for cattle	Cattle excreta fertilize pasture and market garden
SLI5	Pasture to feed cattle and goat, market garden by-products to feed poultry and pig; Use of compound animal feed for pig and poultry	Cattle and goat excreta fertilize pasture, poultry and pig excreta fertilize market garden
ME1	Pasture for cattle and goats, market garden and food crop by-products to feed pigs; Use of compound animal feed for cattle, goats and pigs	Cattle and goat excreta fertilize permanent pasture
ME2	Pasture to feed cattle, market garden and food crop to feed pig and poultry; Use of compound animal feed for cattle and pigs	Cattle excreta fertilize pasture, market garden and food crops, pig excreta fertilize market garden and food crops
ME3	Pasture and sugarcane to feed cattle, sugarcane and market garden to feed pigs; Use of animal feed for pigs	Cattle excreta fertilize pasture, pig excreta occasionally fertilize market garden
ME4	Food crop by-products and sugarcane feed pigs, pasture feed donkeys	Pig and donkey excreta fertilize food crops and market garden
ME5	Pasture and sugarcane straws feed cattle; sugarcane straws, agroforestry and market garden to feed pigs; Use of compound animal feed for pigs	Cattle excreta fertilize pasture, pig excreta fertilize market garden before planting
MCI2	Use of compound animal feed for pigs	Pig excreta to fertilize market garden
MCI3	Pasture to feed cattle, market garden and food crop by-products to feed pigs; Use of compound animal feed for pig and poultry	Cattle excreta fertilize pasture, pig and poultry excreta occasionally fertilize food crop and market garden
MCI4	Use of compound animal feed for pigs	Pig excreta so fertilize sugarcane
MCI5	Use of compound animal feed for rabbit and pigs	Very occasional use of pig and rabbit excreta so fertilize sugarcane

**Table 4** The 3 patterns of crop-livestock integration implementation identified using the graphical Bertin (1977) method from crop-livestock integration and work with animal's criteria. The lighter the colors, the more agroecological the practices considered.

Patterns	Pattern 1						Pattern 2					Pattern 3		
	SLI1	ME4	SLI2	SLI5	SLI4	SLI3	ME5	MCI3	ME3	ME2	ME1	MCI4	MCI2	MCI5
Use crop products as animal feed <sup>1</sup>	A	A	B	B	B	B	B	B	B	B	B	C	C	C
Use of animal excreta to fertilizers <sup>2</sup>	A	A	A	A	A	A	B	B	B	B	C	A	A	B
Delegation of work with animals	A	C	A	A	A	C	A	B	B	C	A	B	B	B

<sup>1</sup> A = 100% crop-product feed, B = both crop products and compound feed, C = 100% compound feed.

<sup>2</sup> A = 100% use of animal excreta, B = partial use of animal excreta, C = no excreta collection.

<sup>3</sup> A = Shared with family help, B = shared with permanent workers and volunteers, C = never shared.

Moore 2012). Only four farms use ruminant excreta to fertilize market gardens, one of them with field grazing of residues and the three others in a collect-and-carry system. The farms that used monogastric excreta were also in a collect-and-carry system. Regarding this practice, and in accordance with Stark et al. (2016), we ran Bertin analysis using three classes of how farmers used and managed animal excreta to fertilize crops: (A) 100% use of animal excreta, (B) partial use of animal excreta, and (C) no excreta collection (Table 4).

Eleven farmers delegated work with livestock to either permanent workers (ME3, MCI2, MCI3 and MCI4), family help (SLI1, SLI2, SLI4, SLI5, ME1, ME5, MCI2, MCI3, MCI4) and/or volunteers (MCI4, MCI5; Table 3). Permanent workers were employed to decrease the farmer's workload on animal production due to a large herd (pigs) or flock (laying hens) kept indoors (MCI3, MCI2, MCI4) and to roster some free time on Sundays (ME3). When work with animals is shared with a family or non-family volunteer/helper (intern, neighbor), they generally help on the whole farm and therefore also on livestock-related activities. The remaining farmers (SLI3, ME2, and ME4) stated that they would not entrust their animals to someone else. Consequently, the Bertin analysis retained 3 classes of how farmers delegated work with animals: (A) shared with family help, (B) shared with permanent workers and volunteers, and (C) never shared (Table 4).

#### 2.4.3 Analysis of farmers' perceptions of the job and work with animals

In a third step, qualitative data on farmers' perceptions of the job and work with animals was analyzed using a framework proposed by Fiorelli et al. (2012). Five classes of rationalities were retained according to Fiorelli et al. (2012): economic, technical (the productive dimension of work), relational (the pleasure felt by doing the job and contact with the animals), identity (personal or professional achievement), arduousness (physical engagement, ability to perform non-repetitive tasks and freedom of action). This analytical framework provides an understanding of farmers' choices and expectations around

their work. The data was classified into five types of rationalities (economic, technical, relational, identity, arduousness).

## 3 Results and discussion

### 3.1 Crop-livestock integration shaping work organization

#### 3.1.1 General characteristics

Three patterns of CLI were identified (Table 4), each with a specific set of characteristics (Table 5).

Pattern 1 (n=6 farms) was characterized by strong use of CLI practices. In pattern 1, 100% or a majority of animal feed came from on-farm, and all 6 farms collected animal excreta to fertilize crops. On-farm animal feed was composed mainly of pasture for ruminants, complemented with crop by-product: sugarcane products (straw, silage, or tops), market-garden and food crops (mainly non-marketable biomass) or crop by-products from orchards. All collected excreta was used to fertilize market-garden and food crops and/or trees (Table 3). Pattern-1 farms were the smallest of the sample in terms of land area and herd size (Table 5), with an average of two different animal species on the farm. Pattern 1 counted all the SLI farms plus ME4 (Table 4).

Pattern 2 (n=5 farms) was characterized by moderate use of the two CLI practices, i.e. animals were fed with both on-farm crop products (market-garden by-products, sugarcane mainly straw) and compound feed. Farmers practiced partial collection of animal excreta to fertilize the crops (market-garden and food crops). Pattern-2 farms had the largest land area of the sample, and the largest sugarcane and pasture area. They also reared more ruminants (mainly cattle) than the two other patterns (Table 5). Pattern 2 counted four ME farms and one MCI farm (Table 4).

Pattern 3 (n=3 farms) was characterized as intensive productivity-driven farms where animals were fed exclusively with compound feed, but they used animal excreta to fertilize



the crops more regularly than in pattern 2. Mainly pig excreta were used to fertilize sugarcane and/or market-garden crops. Pattern-3 farms had the largest herd size and reared more monogastrics than the other two patterns. Pattern-3 farms also cultivated the smallest pasture area and the largest market-garden area. Pattern 3 counted three MCI farms.

### 3.1.2 Work duration and arduousness

These three patterns had different work durations (Table 5). Pattern 3 had more seasonal work (an average of 13.8 h/d) and routine work (an average of 3.8 h/d) than Pattern 2 (an average of 8.2 and 3.4 h/d, respectively) and Pattern 1 (an average of 5.5 and 2.4 h/d, respectively). The efficiency of routine work was higher in Patterns 2 and 3 with a lower time spent per animals (0.12 h/d/TLU) than in Pattern 1 (0.26 h/d/TLU) (Table 5). Higher herd sizes improve the quantity of routine work. This increase in efficiency would be due to economies of scale, driven by the high numbers of animals rather than by the benefits of being able to mechanize, since most tasks are manual on MCLS farms. The increase in quantity of routine work appears to be incompatible with the additional time required to implement CLI practices. In such systems, crop

products are used as animal feed on a daily basis. Like milking in dairy systems, this task is the most structured and time-dominant feature of the routine work, effectively shaping the organization of work on the farm (Cournut et al. 2018). Pattern-1 farms spent more time using crop-products as animal feed (an average of 243.3 h/year) than Pattern-2 farms (an average of 226.9 h/year), whereas farmers in Pattern 3, who have more animals and more routine work, did not perform this practice. Pattern-3 farmers stressed the huge time burden required to harvest the high volumes of crop products needed to feed large-size industrial animal units: “[harvesting, transporting and giving crop products] is arduous work, and my enterprise is industrial-scale, I don’t just have 20 rabbits which would be so much easier” (MCI5). Consequently, farms in Pattern 3, which are oriented toward intensified animal systems, preferred to rely on commercial feed rather than use on-farm crop products.

Pattern-3 farms spent more time using animal excreta to fertilize crops (an average of 29.8 h/year) than Pattern-2 farms (an average of 15.7 h/year) and Pattern-1 farms (an average of 13.3 h/year), because of the higher number of animals. Using animal excreta to fertilize crops was done manually on most farms in our sample, except for MCI2 and MCI4 (Pattern 3)

**Table 5** Mean and median of characteristics (area and size), description of the collective of work, duration, routine work efficiency and time spent performing crop livestock integration practices in the 3 patterns. <sup>1</sup> TLU =

Tropical livestock unit: 1 cattle = 0.8 TLU, 1 pig = 0.2 TLU, 1 Donkey = 0.50 TLU, 1 Sheep = 0.10 TLU, 1 Goat = 0.08 TLU, and 1 rabbit or 1 poultry = 0.01 TLU.

Item	Pattern 1	Pattern 2	Pattern 3
<b>Farm characteristics</b>			
Area (ha)	7.9 (7.6)	17.1 (17.6)	11.5 (11.5)
Crops area (ha)			
Sugarcane	3.6 (3.3)	7.7 (6.5)	5.0 (7.0)
Market gardening	0.9 (0.4)	2.4 (0.5)	3.3 (1.0)
Food crops	0.3 (0.2)	1.4 (1.0)	0.7 (0.0)
Arboriculture	0.7 (0.3)	0.3 (0.1)	0.7 (0.0)
Pasture	2 (2.5)	3.6 (3.0)	1.3 (1.0)
<b>Livestock</b>			
Ruminants (TLU)	5.1 (3.7)	16.4 (14.0)	5.9 (0.0)
Monogastrics (TLU)	3.3 (0.3)	3.6 (1.2)	23.1 (14.0)
Herd (animal number)	44.8 (22)	198 (58)	287 (220)
Number of animal species	2.3 (2.0)	2.6 (3.0)	1.7 (2.0)
<b>Work organization</b>			
Farmer and family (number of workers)	1.0 (1.0)	1.2 (1.0)	1.0 (1.0)
Hired labor (number of full time workers)	0.0 (0.0)	0.1 (0.0)	0.5 (0.5)
Family labor (number workers)	2.2 (2.5)	1.0 (1.0)	1.3 (1.0)
Volunteering (number)	0.8 (1.0)	1.0 (0.0)	0.7 (1.0)
Seasonal Work (h/d)	5.5 (3.7)	8.2 (8.3)	13.8 (9.6)
Routine Work (h/d)	2.4 (1.5)	3.4 (2.6)	3.8 (3.0)
Routine Work efficiency (h/d/TLU)	0.26 (0.22)	0.12 (0.09)	0.12 (0.14)
Use crop products as animal feed (h/year)	243.3 (22)	226.9 (262.9)	0.0 (0.0)
Use of animal excreta to fertilize crops (h/year)	13.3 (13.5)	15.7 (16.3)	29.8 (18.4)

which are intensive pig breeders using a slurry tanker. Extensive animal units (Pattern 1) produced lower volumes of excreta that can be collected more regularly. These low volumes are consistent with the low area to fertilize (an average of 0.9 and 0.3 ha of market-garden and food crops, respectively, in Pattern 1). In Patterns 2 and 3, the farmers preferred to perform fewer harvests and pool their animal excreta. Collection of excreta is regarded as a seasonal task that can be scheduled in periods of low workload. However, most farmers highlighted the time burden of collecting animal excreta as one of main barriers to adopting this CLI practice: “[harvesting, transporting and spreading animal excreta] require a greater amount of work, of time and would increase the cost of labor” (MCI3).

Our research points to a link between production systems, work organization, and implementation of CLI practices. However, this link does not appear to be absolute and depends on local context, farm organization, and the farmer’s motivations (Sneessens et al. 2016). Some farmers, through their work organization and strong motivation for the implementation of CLI practices, manage to combine a productive model and a high valorization of crop products in animal feed (Dieguez et al. 2010). This is especially the case for farmers with low incomes (Pattern 1), as numerous farming families around the world are more likely to invest in their own labor rather than in external inputs (Aubron et al. 2016), particularly if they do not see work with animals as a constraint. More commercial MCLS (Patterns 2 and 3) can improve animal diet by using compound feed based on imported cereals and soya, which may undermine the economic and environmental sustainability of such systems. Moreover, using CLI practices would generate higher workforce requirements in commercial MCLS than in specialized systems (EIP-AGRI Focus Group 2017). The lack of knowledge on how to manage CLI practices and the impact of CLI practices on work organization are a barrier to their adoption (Cortner et al. 2019).

### 3.1.3 Perception of work with animals and impact on CLI practices

Our study highlighted that farmers’ perceptions of their work, especially with animals, also has an influence on level of implementation of CLI practices.

In Pattern-1 farms, which are strong adopters of CLI practices, the farmers’ perceptions of work with animals are grounded in relational and identity rationalities (Fiorelli et al. 2012). Indeed, their profession gives them job satisfaction, personal growth, and well-being: “it soothes me, when I get to the livestock farm I feel calm, I leave my worries outside, it soothes me, I forget all my worries” (ME4). Farmer verbatims show that their relationship with the animals is an important factor in their enjoyment of the work. Tasks with animals are not fully delegated, more for the pleasure the farmers get out

of these tasks than due to mistrust in the workforce: “For the animals, it’s just me and my son as a rule. We can’t afford to delegate that work—if we did, we might come back to find no more animals on the farm!” (SL11), “I prefer to take care of my animals myself. [Otherwise] I think the engagement is not the same” (ME4). The work with animals is done by themselves or with voluntary help from family members. This is consistent with the higher number of family-labor units registered in Pattern-1 farms. Unlike crops, animals require daily attention from experienced people, especially for some fragile animals (small monogastric animals and small ruminants). This daily attention from skilled labor allowed the farmers in pattern 1 to stay abreast of the health of their animals or make sure they were adequately fed—tasks which, if not done properly, can directly impact animal performance and thus the economic performance of the farm. This lack of experienced people to work with animals was also reported by Cortner et al. (2019) in Brazil, where it was found to be a barrier to further adoption of MCLS. According to Cortner et al. (2019), livestock farmers would more readily convert to MCLS than crop farmers because animal systems would already start out with husbandry-skilled farmers.

In Pattern-2 farms, the farmers’ perceptions of work with animals were grounded much more in the economic rationality of their trade and the economic benefits of both CLI and livestock (Fiorelli et al. 2012). They considered CLI as a way to save money by reducing costs on buying in exogenous inputs: “[manure] is free. The time and gas I’m going to use to go out and buy fertilizers in a store is the time I’m going to take to pick it [the manure] up” (ME3). However, they also identified a role for technical services provided by animals, such as a supplier of organic matter: “[use of animal excreta to fertilize crops] avoids the use of chemicals, which helps regenerate the soil” (ME5), and manure is considered to be “better than fertilizers” (ME3).

Pattern-3 farmers are driven by productivity objectives as they ran more intensive and industrial animal activities. This productivity goal was also reflected in the way their perceptions of their profession were grounded in economic and identity rationalities (need for personal and professional accomplishment). Livestock was primarily considered a source of income within the farm. Pattern-3 farmers delegated the work with animals to employees or volunteers. Pattern 3 farmers prefer to give the livestock compound feed rather than on-farm crop-products, as they consider that crop products “don’t enable rapid growth” (MCI5). Pattern-3 farmers perceive crop products as having lower nutritional value and consequently leading to low growth and poor carcass conformation. This low growth and poor carcass conformation are not in accordance with the price grids of the marketing chain, because “selling price decreases as the animals get older” and “the longer you keep an animal on the farm, the more money you lose in feed, labor, and space” (MCI5). In addition,

management of crop-products (collection, transportation, storage, and distribution) appears harder for farmers than with compound feed.

### 3.2 Barriers and opportunities for development of crop–livestock integration practices

There are several technical, social and/or institutional factors that can influence farmers' use of CLI practices, e.g., available adapted infrastructure and machinery, available local knowledge, support (subsidies, and advice) oriented toward specialized agricultural production, absence of a marketing network for diversified production, and more (Dedieu 2019; Garrett et al. 2020). In this study, farmers expressed other factors related to their work organization (perception of work with animals, workforce composition, and trust in employees). Time burden to collect crop products and animal excreta are specific to MCLS, whereas, workforce composition or perception of work with animals could be similar in specialized systems. Nevertheless, they were analyzed in light of their perception by the farmers in this study who are experienced in MCLS systems.

Farmers cited the time burden of collecting crop products and animal excreta as one of major barriers to adoption of CLI practices. This section compiles opportunities already implemented by farmers in this sample or identified in the wider bibliography that can be employed to improve on-farm implementation of CLI practices or stimulate their uptake by late adopters.

According to farmers interviewed in this study, collecting crop products and animal excreta is an arduous task that takes too much time. Mechanized collection of both crop products and animal excreta would be an alternative solution for small farms, mainly Pattern-1 and Pattern-2 family farms where work is essentially manual and physically tiring. However, machinery manufacturers have been slow to develop special machines for agroecologization and small-scale farming (Dedieu 2019), and new technologies would represent an additional cost for farmers. Targeted subsidies are required to help farmers make the transition from manual to mechanized farming.

Following the agroecological vision, which consists of letting nature do the work, grazing or idle-grazing animals offers the opportunity to let animals directly collect feed and fertilize the plot with minimum human intervention, thus reducing input and labor costs. Grazing is widespread in our sample, as 11 of the 14 farms surveyed reared ruminants on pasture. This outdoor practice essentially concerns ruminants, as few farms in Guadeloupe rear monogastrics outdoors and there are issues to address, especially around animal welfare since most monogastric breeds reared in Guadeloupe have been selected for high performance indoors on a compound feed diet.

Some farmers (mainly in Pattern 1 and 2) pointed out a negative cost-benefit economic ratio of employing an additional person to implement CLI practices to save on external input costs. According to Aubron et al. (2016), intensification of labor is the pathway most commonly taken (rather than investing in equipment and external inputs) to increase the production output of farms (often family farms) around the world and at different points in time. This goes in hand with the creation of agricultural jobs (Duval et al. 2021) which is desirable for both developing and industrialized countries to reduce rural depopulation and unemployment. However, according to the farmers, the labor law in industrialized countries (and also in force in our study area) means that the economic benefits of CLI failed to cover the additional cost of employing a new person to do the job. Consequently, when CLI practices are performed, farmers preferred to do the job themselves: as they do not "count their own time," the farmers considered this amount of extra CLI work acceptable. Our intention here is not to criticize the labor law in industrialized countries but to propose strategies that would make CLI practices more attractive for farmers in Guadeloupe and other tropical regions. Targeted supportive policies and market governance offer an opportunity to overcome the workload problem (Cortner et al. 2019). Whether they are oriented toward helping to create new jobs, training to have more skilled employees, or payment for ecosystem services, such policies would likely influence farmers' perceptions of CLI practices (Cortner et al. 2019). However the lack of objective data on impact of CLI practices is a barrier to the development and thus adoption of adequate policies (Cortner et al. 2019; Garrett et al. 2020). Market governance can address consumer expectations for products of high nutritional and environmental quality, allowing producers to develop labels or other forms of differentiation to create a niche market where farmers could capture more value from the production and consequently be able to pay an additional employee.

For the more commercial farms (Patterns 2 and 3), cooperation at territorial level is a viable alternative solution that would enable farmers to share crop products or skilled labor to collectively bear the additional cost of CLI practices and resolve or reduce the allied workload problems (Moraine et al. 2016; Martin et al. 2016). Typical cooperative initiatives include shared employees, task delegation or tasks sharing between farmers, and shared equipment to increase productivity (Andersson et al. 2005). Nevertheless, this strategy needs to take into account the local context to propose organizational innovations, social coordination, and public policies to support CLI practices at territorial level (Moraine et al. 2016).

### 3.3 Methodological considerations

The methodology presented here was built on a combination of quantitative and qualitative methods within a conceptual

framework of local systems (Stark et al. 2016). The quantitative component relies partly on the QuaeWork method to quantify and qualify work organization. Although this method has already been tested in several tropical countries (Hostiou and Dedieu 2012), it was originally designed for livestock farming systems and husbandry-related practices (Cournut et al. 2018). Here, it was applied to tropical MCLS farms which encompass a large number of crop activities and several animal units. Consequently, some adaptations were needed to meet the objectives of this study. The conceptual model proposed by Stark et al. (2016), where species were pooled into compartments based on their agronomic features, allowed us to overcome the time constraint and difficulties involved in asking farmers to inventory all their crop management tasks. This strategy enabled us to implement this method for a large level of diversity as recommended in the context of agroecological transition.

Regarding the qualitative component, we used the quantitative results as an intermediary to stimulate discussions with farmers on their perceptions of how CLI practices articulate with their work organization. However, we did not consider the views of employees, volunteers, or family members, which are also involved in work organization. We used the conceptual framework of livestock farming systems developed by Gibon et al. (1999), which considers the farmer as driver of the system and work organizer (Dedieu and Servière 2012; Cournut et al. 2018), but the perceptions of these other labor resources, especially in terms of work with animals and CLI practices, could bring out additional considerations that the farmers themselves missed (Malanski et al. 2019). Similarly, we did not address the gender issue, whereas women play an active role in the success of some development programs, especially on smallholder farms (Doss 2017). Moreover, we focused on farms that have already implemented CLI practices, on the assumption that they would be well placed to provide insights for new adopters. It would also be instructive to capture the vision of farmers who do not implement CLI practices, especially on their perceptions of work with animals, which can differ between crop producers and breeders (Cortner et al. 2019).

## 4 Conclusion

This research points to a link between production systems, implementation of CLI practices, and work organization. We identified three patterns of how CLI shapes work organization, and the duration of CLI work was different between these three patterns. We also showed for the first time that farmers' perceptions of farmwork, and especially work with animals, also influence the level of implementation of CLI practices. In Pattern 1, work with animals is done by the farmers themselves or by skilled persons from their familial circle, i.e., people they trust. In Pattern 3, the role of animals is much more centered

around economics, i.e., animals were considered as a source of income within the farm. Consequently, Pattern-3 farms more readily delegate work with animals, including crop–livestock integration practices, to employees or volunteers. Regardless of their CLI–work pattern, all farmers cited the time burden of collecting crop products and excreta as one of the major barriers to implementation of CLI practices. Mechanized collection of excreta, direct collection by animals, development of adequate supportive policies, and cooperation between farms would be a set of solutions to this issue, but these strategies have to account for the local context and objectives of each farm. In the context of the agroecological transition which require the adoption of agroecological practices by a majority of farms, this work raises the question of work organization in these systems, the impact of their higher work demand on production costs, and consumer willingness to pay a price premium for agroecologically-farmed food. Further research is needed to perform a socio-technical analysis around CLI practices in order to better understand the barriers to uptake of agroecological crop–livestock strategies. This research is all the more relevant in the current context of soaring input prices (feed and fertilizer) on the international market, that leads to shone a new look at the use of CLI practices.

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**Authors' contributions** All authors contributed to the study conception, design, writing, and visualization. Methodology: NH and AF – Formal analysis: AF and NH – Investigation: AF and GA – review and editing: AF – Supervision: AF. Project administration and acquisition : Project 1 = GA and AF; Project 2 = NH and AF.

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**Data availability** The datasets generated during the current study are available from the corresponding author on reasonable request. Investigation reports are in French.

**Code availability** Not applicable

## Declarations

**Ethics approval** The authors declare compliance with ethical standards.

**Consent to participate** Verbal informed consent was obtained from farmers prior to interview.

**Consent for publication** Verbal informed consent was obtained from farmers prior to interview.

**Conflict of interest** The authors declare no competing interests.

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