Work organization as a barrier to crop-livestock integration practices: A case study in Guadeloupe

Audrey Fanchone, Gisèle Alexandre, Nathalie Hostiou

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

Audrey Fanchone [a], Gisèle Alexandre [a], Nathalie Hostiou [b]

[a] INRAE, URZ, Centre Antilles Guyane, Domaine de Duclos, Prise d'Eau, 97170 Petit-Bourg (Guadeloupe), France
[b] Université Clermont Auvergne, AgroParisTech, Inrae, VetAgro Sup, UMR1273 Territoires, 63000 Clermont-Ferrand, France

Abstract: *Crop–livestock integration is thought to increase system autonomy and resilience by transitioning system components into a circular economy. Like most agroecological practices, crop–livestock integration is considered time- and labor-intensive. We hypothesized that work characteristics (organization, duration, and arduousness) and subjective factors related to work with animals shaped the implementation of crop–livestock integration practices in mixed crop–livestock systems and vice versa. The Qualification and Evaluation of Work method (QuaeWork) was coupled with qualitative interviews. This framework was implemented on 14 farms selected from a typology of mixed crop–livestock systems in Guadeloupe (French West Indies), where the high cost of labor raises tension between work organization and agroecological practices. Three patterns of crop–livestock integration shaped work organization: family farms with strong crop–livestock integration (Pattern 1, 6 farms), farms with moderate crop–livestock integration (Pattern 2, 5 farms), and intensive productivity-oriented farms (Pattern 3, 3 farms). These patterns have different farm characteristics and work organizations. Pattern 2 spent more time using crop by-products as animal feed (on average 253 h/year) than Pattern 1 (on average 222 h/year), whereas Pattern 3 did not use crop-products to feed animals. Farms in Pattern 3 spent more time using crop excreta to fertilize crops (on average 29.8 h/year) than Pattern 2 (on average 19.6 h/year) and Pattern 1 (on average 13.4 h/year). In Patterns 1 and 2, the low availability of family labor, and lack of the presence of skilled employees, may hold back whole-farm crop–livestock integration development and increase in animal units, whereas, in Pattern 3, management of the nutritional value of crop by-products and the cost related to employing additional persons would do so. The subjective link to animals can be more relational (Pattern 1), practical (Pattern 2), or economic (Patterns 2 and 3) regarding farmers' objectives. Adapted mechanization, direct collection of feed and deposition of feces by animals, targeted supportive policies and market governance, and organizational innovation beyond the farm level are discussed as levers that can be operated depending on the pattern.*

Keywords: *work organization, integrated crop–livestock system, family labor, agroecology*

Acknowledgments: *This study formed part of the AgroEcoDiv Project funded by the European Regional Development Fund (FEDER) (grant 410-00235) and the Regional Council of Guadeloupe (grant 410-00232). This research was also supported by GIS Avenir Elevage. We thank the 15 farmers who were interviewed for this study. We hold in memory farmer MCI1, who started this work with us but passed away before the surveys were completed.*

Introduction

Intensive farming was promoted under the postwar effort to feed the global population. This "conventional agriculture" transformed farm structures, driving them toward decoupling of crop and animal production and specialization (Garrett *et al.,* 2020), but has also shown limits in terms of environmental impacts (soil leaching and erosion, decrease in soil nutrient content, loss of biodiversity, groundwater pollution, and greenhouse gas emissions). Agroecology, which has been defined as a movement, a scientific discipline, or a set of practices, is now emerging as a solution to increase production and meet the growing demand for agricultural products while decreasing the negative externalities of conventional agriculture.

Agroecology, as a set of practices, promotes the introduction of new and more sustainable techniques in farming systems (Wezel *et al.,* 2014). These new practices affect farmers' working conditions (Aubron *et al.,* 2016; Bendahan *et al.,* 2018) because they can compete with other interventions on the farm or can require an initial learning time that can quickly discourage farmers (Timmermann and Felix, 2015).

These working conditions influence the ways in which farmers appropriate and implement agroecological practices and are engaged in the agroecological transition.

Among the diversity of agroecological practices, crop–livestock integration (CLI) is highlighted because of its benefits for sustainable food production, livelihood improvement, and efficiency (improvement of resource use). CLI exploits the synergies between cropping and livestock systems, allowing mixed crop–livestock systems (MCLS) to connect environmental, economic, and social objectives such as the mitigation of climate and economic risks and cost saving 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 gathering mainly the use of crop products and by-products to feed animals, the use of animal excreta to fertilize crops, and animal draught power. Worldwide, there is a wide spatial or temporal variety in the ways that CLI practices are employed, for example, synchronized integration by the use of dual-purpose crops, integration by rotation, cut-and-carry systems, or between-farm integration generating different types of MCLS, etc. In tropical areas, MCLS are still rooted in the landscape, especially on smallholder farms where they provide households with both food and income (Herrero *et al.,* 2010). In temperate areas, the general trend is toward a decoupling of crop and livestock systems leading to "segregated" MCLS (Garrett *et al.,* 2020).

At the farm level, several factors can affect the implementation of CLI practices by farmers: amount of subsidies, decrease in input costs, level of education of farmers, or lack of professional organizations (Fanchone *et al.*, 2020). MCLS are often perceived to have lower profitability and involve 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) work characteristics can limit CLI implementation (Ryschawy *et al.*, 2012, Cortner *et al.,* 2019), especially because of the presence of animals. Animal management has specific features compared to crop activities: the work is done on a daily basis and many tasks are not postponable (Hostiou and Dedieu, 2012). This requires more labor and more skilled labor than extensive or completely mechanized systems (Cortner *et al.,* 2019; Garrett *et al.,* 2020). Subjective factors also called "farmer singularities" by Coquil *et al.* (2018), such as animal and farmer welfare, contact with nature, or identity, must also be taken into account in addition to the economic rationality when promoting the development of CLI (Fiorelli *et al.,* 2012).

Most of the research on MCLS has focused on the economic and environmental impacts of CLI at both the farm (Sneessens *et al.,* 2016; Stark *et al.,* 2016) and territorial levels (Moraine *et al.* 2016). Few studies have addressed the issue of labor in the management of crop and livestock operations, among which few have performed a systemic analysis of work organization (Delecourt *et al.,* 2019). Moreover, methods developed to address work organization by modeling farm-level crop and livestock organization did not account for farmers' needs and knowledge in the analysis of how they implement the practices (Madelrieux and Dedieu, 2008; Hostiou and Dedieu, 2012). To our knowledge, only Malanski *et al.* (2019) included subjective indicators in their analytical framework.

The objective of this study was to identify how the implementation of CLI practices is affected by farmers' work, and to identify barriers and levers to improve the development of CLI practices. To do that, we combined a quantitative analysis of work organization with qualitative interviews to consider the trade-offs between the objective factors (availability of workforce, labor time) and subjective factors (farmers' singularities) that influence the implementation of these practices. We focused (i) on CLI, a complex agroecological practice, because of its central role in MCLS functioning and performance; and (ii) on farms that already implement CLI because of their skill and feedback on these practices that can benefit other farmers in their learning process (Coquil *et al.,* 2018; Delecourt *et al.,* 2019). We used the

conceptual framework of livestock farming system (Gibon *et al.,* 1999), which considers the farmer as a driver of the system and the work organizer (Dedieu and Servière, 2012; Cournut *et al.,* 2018) to perform a systemic analysis of farms.
This study was carried out in Guadeloupe, which encompasses a broad diversity of farming systems engaged at different stages in the agroecological transition process (Fanchone *et al.,* 2020). Like other Caribbean islands, Guadeloupe concentrates strong environmental and socioeconomic mutations at small spatial (insularity, coexistence of several agricultural models) and temporal (speed of evolution of phenomena) scales. The significant access to capital and the high cost of labor because of subsidies from France and the European Union make Guadeloupe a good laboratory to study the tension between work organization and implementation of agroecological practices.

Material and methods

Study area and sampled farms

This study was carried out in Guadeloupe, a French insular archipelago (1,434 km²) in the Caribbean Sea (latitude 16°13′ North, longitude 61°34′ West). Guadeloupian agriculture is mainly based on small MCLS with an average size of 4.1 ha, which represent 80% of the farms in the study area (Stark *et al.,* 2016). Sugarcane and banana, two highly subsidized export crops, cover most of Guadeloupe's agricultural land (31,400 ha), where they represent 45% (sugarcane) and 8% (banana) of the arable farmland (Fanchone *et al.,* 2020). Pasture and fallow currently account for close to half of the arable land of both islands. 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 with one or both of the two major exports crops. Farms may also include market gardening, orchards, or tuber and fruit production. Products destined for the local market do not cover local demand, and so the island is exposed to strong external dependence. The agricultural trade balance shows a large deficit, as 80% of the food comes from imports (Fanchone *et al.,* 2020). Moreover, both livestock and crop activities are heavily reliant on imported and increasingly expensive feed concentrates and mineral fertilizers.
Sampling was based on farms that already implement CLI because of their skill and feedback on these practices that can benefit other farmers in their learning process (Coquil *et al.,* 2018; Delecourt *et al.,* 2019). We thus used the MCLS typology of Stark *et al.* (2016) developed on a set of 111 MCLS farms in Guadeloupe to build the sample of farms interviewed. In this typology, farms were discriminated into three types of MCLS based on the level of production factors and diversity of production: (i) small labor-intensive farms (SLI), (ii) medium extensive farms (ME), and (iii) medium capital-intensive farms (MCI). ME farms would have a more extensive combination of production than SLI and MCI farms. SLI farms would have a lower agricultural area and lower access to capital than ME and MCI farms (Stark *et al.,* 2016). Five livestock farmers considered as representative (for products and production factors) of each type and covering the diversity of agriculture in Guadeloupe were selected for data collection. Unfortunately, one of the farmers (MCI1) died during the data collection process, which was not therefore completed, and so 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 gardening (n = 12), followed by sugarcane (n = 11), pasture (n = 10), food crops (n = 8), and arboriculture (n = 7). Because of the purpose of the study, only farms with livestock were chosen. Since all rabbit livestock in the sample were fed exclusively on industrial feed, rabbits were considered monogastric in this study. Ruminants (cattle, goat, sheep, or donkey) were reared on 11 farms, and

monogastrics (pigs, poultry, and rabbit) were reared on 12 farms. Most of the farms (n = 10) reared more than one animal species, with a maximum of four different animal species on the same farm (SLI2 and SLI5).

Data collection

Data were collected during two interviews with farmers. During the first survey, structural and quantitative data on work organization and agroecological practices were collected. The second survey collected qualitative data focusing on how farmers perceived and managed CLI in relation to their labor force.

For the first survey, we used the QuaeWork method developed by Hostiou and Dedieu (2012) to collect quantitative data on work organization. QuaeWork characterizes and qualifies the work organization taking into account the interactions between the farm technical system, the workforce, and all on-farm and off-farm activities. It also aims to identify the reasons underpinning the farm organization. To address work content (the "what"), two types of tasks are defined 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. This work is quantified in hours per day. The labor component (the "who") is handled by differentiating two categories of farm labor. The basic group comprises workers for whom agricultural work predominates in time and income, such as a farmer, a farming couple, or associates. The workforce outside the basic group represents workers (i) who occasionally intervene in farm work (children, mutual help, agricultural company, equipment cooperative, etc.); (ii) who do not share any responsibility for work organization (full-time or temporary wage earners); and (iii) whose income does not depend directly on the farm (retired relatives, spouse working full-time off the farm, etc.).

The QuaeWork method has been adapted to the Guadeloupian farms because they can encompass 20 different production activities (Fanchone *et al.,* 2020). 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 therefore used the conceptual model developed by Stark *et al.* (2016): different species were pooled in compartments according to their agronomic features (crop cycle, species, storage, etc.) rather than accounting for all species. Because of their central role in Guadeloupian agriculture, sugarcane and banana are represented as specific compartments. The other four cropping compartments include crops traditionally grown in Guadeloupe, according to their production cycle and management practices: tubers (often cultivated on mounds, with a medium-term cycle), market gardens (short cycle, often intercrops), fruit (medium-term cycles, specialized), and agroforestry (perennial crops). All livestock compartments were addressed in relation to the objectives of the study. During this first survey, data were also collected on CLI (using crop products and by-products as animal feed and using animal excreta to fertilize crops) practices implemented on the farm. The time to collect, transport, and distribute crop products or spray animal excreta (hours per practice) and frequency (number per year) of these practices were asked of the farmers. They were allowed to calculate the time required yearly to perform CLI practices (hours/year).

For the second survey, we used a more qualitative semi-directive interview format to better understand farmers' subjective relationship to work, farmer perceptions of CLI practices, and the role of animals within the farm. This second survey started with a validation with farmers of the results of the first interview (work collective and work organization, management of work with animals and CLI practices). Then, farmers were asked to explain (i) the tension that emerges from having animals and performing CLI practices in their work organization, (ii) their motivations for having animals on the farm and performing CLI practices despite this tension, and (iii) the main limits they identified for the development of these practices.

Item	SLI1	SLI2	SLI3	SLI4	SLI5	ME1	ME2	ME3	ME4	ME5	MCI2	MCI3	MCI4	MCI5
Farm characteristics														
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														
Polygastrics (TLU)	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
Work organization														
Permanent workers (unit)														
Farmer and family	1	1	1	1	1	2	1	1	1	1	1	1	1	1
Hired labor								0.14			1	0.28	0.5	
Seasonal workers (type)														
Family labor (number)	3	3	1	2	4		2			1	1	2	2	1
Family labor frequency[1]	S	R+O	O	O	R+O		O			O	O	R	O	R
Volunteering (number)		2		1	1				1	5			1	1
Services providers	+	-	-	+	+	+	+	+	+	-	-	-	+	+
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[2]	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

Table 1: Characteristics (area and size), description of the workforce, duration, routine work efficiency and time spent performing crop livestock integration practices in the 14 mixed farms. *[1] O = Occasionally; R = Regularly; S = Seasonally. [2] F = Family; E = Employee; V = Volunteering*

Data analysis

The data were analyzed in two steps. In the first step, work organization (workforce, routine and seasonal work), delegation of work with animals, and time devoted to implementing CLI practices (using crop products as animal feed, using animal excreta for fertilizer) were quantified or described using an Excel file produced by the QuaeWork method (Hostiou and Dedieu, 2012). The number of animals was expressed in tropical livestock unit (TLU) to compare different species: 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. Data from the second survey on farmers' subjective relationship to work, farmer perceptions of CLI practices, and the role of animals within the farm were collected in a written questionnaire that was entered immediately after the survey in a Word document to ensure faithful use of farmers' verbatim statements.

In the second step, we used data from the first step to build variables allowing us to identify groups of farms (Bertin, 1977). These variables were categorized in three classes (A, B, and C) by opposing the two extreme farms. Classes were built by progressively considering the other farms until no additional category was necessary. The classes of each variable were combined in a graphic representation to distinguish the forms of work organization by building a "Bertin table," 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 gray, and dark gray) was used to distinguish the classes of each variable, with darker colors indicating more change for the given variable.

Five variables were retained from the first step of data analysis, that is, two variables allowing us to define and characterize the level of CLI (using crop products to feed animals and using animal excreta to fertilize crops) and three variables allowing us to characterize work with animals and work organization (delegation of work with animals, family labor outside the basic group, and non-family labor outside the basic group). 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. The use of crop products is a daily practice that cannot be aggregated or postponed and is part of routine work, whereas the use of animal excreta to fertilize crops is easier to postpone and/or aggregate over a given period and is consequently part of seasonal work. Moreover, when classes overlapped, priority was given to the higher contributor to work organization, for example, permanent workers that are hired labor are more regularly present on-farm and thus contribute more to the work with animals than family labor, which is more punctual.

Qualitative data on farmers' job perceptions and work with animals were analyzed using a framework proposed by Fiorelli *et al.* (2012). This analytical framework provides a better understanding of farmers' choices and expectations of their work. The data were classified according to five types of rationalities (economic, technical, relational, identity, work arduousness).

Categorization of crop–livestock variables

Among the 14 farms studied, 11 used crop-products to feed animals (the 5 SLI, the 5 ME, and MCI3; Table 2). Four of the 14 farms have to transport crop-products from one site to another on the farm (ME1, ME2, ME5, MCI3), while one farm (SLI5) used crop-products from another farm. Ruminants (cattle, goats, and sheep) are mainly reared on pasture. As observed by Stark *et al.* (2016), feeding animals with crop-products mainly involved pig production (10 farms). Seven farms with pigs used food crop and market garden products (SLI5, ME1, ME2, ME3, ME4, ME5, MCI3), whereas three farms used sugarcane straw and by-products (SLI2, SLI5, ME2). Sugarcane was mainly used for ruminants (SLI1, SLI2, SLI4, ME3, ME5), whereas food crop and market garden products were used by two farms with

ruminants (SLI1 and 2). Twelve farms used industrial animal feed to supplement the animal diet (SLI1, SLI3, SLI4, SLI5, ME1, ME2, ME3, ME5, MCI3) or as the sole source of feed (MCI2, MCI3, MCI4 and MCI5). Industrial feed was used as the sole source of feed for the production of monogastrics (pigs and poultry, or rabbit). Regarding this practice, and in accordance with the previous results of Stark *et al.* (2016), we defined three classes of how farmers used crop-products to feed animals in the Bertin analysis: 100% crop products as animal feed (A), majority of crop products coupled with industrial feed (B), and 100% industrial feed (C) (Table 3).
Thirteen farms used animal excreta to fertilize crops (Table 2). As reported by Stark *et al.* (2016), organic fertilization practices mainly involved the direct deposit of animal excreta in the field (mainly for ruminants, 10 farms) or using excreta to fertilize market garden and food crops (11 farms). Direct deposit of excreta by ruminants becomes completely virtuous only when the farmers carry out crop rotation, field grazing of residues, or collecting and carrying excreta (Bell and Moore 2012). Only four farms use ruminant excreta to fertilize market gardens, one with field grazing of residues (SLI1) and the others in a collect-and-carry system (SLI4, ME2, ME4). The farms that used monogastrics' excreta were also in a collect-and-carry system. Regarding this practice, and in accordance with the previous results of Stark *et al.* (2016), we defined three classes of how farmers used and managed animal excreta to fertilize crops in the Bertin analysis: total use of animal excreta (A), partial use of animal excreta (B), and no collection (C) (Table 3).

	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 industrial animal feed for cattle, sheep and poultry	Cattle excreta fertilize pasture, poultry and sheep excreta fertilize market garden and food crop
SLI3	Arboriculture by-products to feed rabbits; Use of industrial animal feed for rabbits	Rabbit excreta fertilize trees
SLI4	Pasture and sugarcane to feed cattle; Use of industrial 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 industrial 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 industrial 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 industrial 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 industrial animal feed for pigs	Cattle excreta fertilize pasture, pig excreta fertilize market garden before planting
MCI2	Use of industrial 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 industrial animal feed for pig and poultry	Cattle excreta fertilize pasture, pig and poultry excreta occasionally fertilize food crop and market garden
MCI4	Use of industrial animal feed for pigs	Pig excreta so fertilize sugarcane
MCI5	Use of industrial animal feed for rabbit and pigs	Very occasional use of pig and rabbit excreta so fertilize sugarcane

Table 2. Crop-livestock integrations practices in the 14 mixed farms in Guadeloupe.

Name of the patterns	Pattern 1						Pattern 2					Pattern 3		
	1	9	2	5	4	3	10	13	8	7	6	14	12	15
Farm	SLI 1	ME 4	SLI 2	SLI 5	SLI 4	SLI 3	ME 5	MCI 3	ME 3	ME 2	ME 1	MCI 4	MCI 2	MCI 5
Use crop products as animal feed	A	A	B	B	B	B	B	B	B	B	B	C	C	C
Use of animal excreta to fertilizers	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
Family labor outside the basic group	B	C	A	A	B	B	B	A	C	B	A	A	B	A
Non family labor outside the basic group	B	B	B	B	B	A	B	C	C	B	B	C	C	B

Table 3. The 3 patterns of work organization identified from CLI and work with animals criteria.

Categorization of work organization variables

All the farms were managed by one (13 farms) or two farmers (1 farm) (Table 1), which composed the basic group. One farm was managed by a woman (SLI3). The farmers used family labor outside the basic group, which mainly involved the farmer's son, partner, mother, nephew, uncle, or cousin. Family members were considered as help as they are unpaid. Family workers outside the basic group had different implications for carrying out tasks: they can be regular (SLI2, SLI5, MCI3, and MCI5), occasional (SLI2, SLI3, SLI4, SLI5, ME2, ME5, MCI2, MCI4), or seasonal (SLI1). Three forms of family work outside the basic group allowed us to distinguish three classes in the Bertin analysis: farms using regular family work (A), farms with occasional or seasonal family labor (B), and farms without family assistance (C) (Table 3).
Considering the non-family workforce outside the basic group, hired labor is widespread in the sample, with different forms, including employees (ME3, MCI2, MCI3, and MCI4) or service providers (SLI1, SLI4, SLI5, ME1, ME2, ME3, ME4, MCI4, and MCI5), whereas seven farms (SLI2, SLI4, SLI5, ME4, ME5, MCI4, and MCI5) used volunteers (interns, neighbors) (Table 1). The four farms with permanent employees (ME3, MCI2, MCI3, and MCI4) have a high number of tethered or indoor animals. Service providers were assigned to tillage or tasks related to sugarcane management (planting, weeding, harvesting). Consequently, three classes of non-family workforce outside the basic group were retained for the Bertin analysis: farms without a non-family workforce outside the basic group (A), farms using volunteers and service providers (B), and farms with hired labor (C) (Table 3).
Eleven farmers delegated work with animals, to permanent workers (ME3, MCI2, MCI3, and MCI4), family help (SLI1, SLI2, SLI4, SLI5, ME1, ME5, MCI2, MCI3, and MCI4), or volunteers (MCI4 and MCI5; Table 1). Permanent workers were employed to decrease work in animal production due to a large number of animals (pigs or laying hens) kept indoors (MCI3, MCI2, and MCI4) and to organize some free time on Sundays (ME3). When work with animals is shared with a family or non-family volunteer/helper (intern, neighbor), that person generally helps on the whole farm and therefore also in livestock-related activities. The remaining farmers would not entrust their animals to someone else (SLI3, ME2, and ME4). Consequently, we retained three classes of delegation of work with animals in the Bertin analysis: shared with family help (A), shared with permanent workers and volunteers (B), and not shared (C) (Table 3).

Results and Discussion

Patterns of work organization in relation to crop–livestock integration

General characteristics of the patterns

Three patterns of CLI were identified (Table 3) with different characteristics (Table 4). Pattern 1 (6 farms) was characterized by a strong use of CLI practices with 100% or a majority of crop products used to feed the animals and all animal excreta collected to fertilize crops. Pattern 1 had more seasonal family workers (on average 2.2) than the other two patterns. Seasonal family workers were mainly composed of regular family workers (2 farms) or occasional assistance (4 farms). For the non-family seasonal workers (volunteers, service providers, …), farmers used volunteers and service providers (5 farms) or did not have outside basic group labor (1 farm). Volunteering represented 1.3 persons. Work with animals was delegated to family labor or not shared. This pattern counted all the SLI farms and ME4 (Table 3). In Pattern 1, the farms are the smallest of the sample, with on average 7.9 ha, 5.1 TLU of polygastrics, and 3.3 TLU of monogastrics. Average animal herd size was 44.8 head with on average two different animal species on the farm.

Item	Pattern 1	Pattern 2	Pattern 3
Farm characteristics			
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)	3.7 (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)	0.0 (0.0)
Pasture	2 (2.5)	3.6 (3.0)	1.0 (0.0)
Livestock			
Polygastrics (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)
Work organization			
Farmer and family	1.0 (1.0)	1.2 (1.0)	1.0 (1.0)
Hired labor	0.0 (0.0)	0.1 (0.0)	0.5 (0.5)
Family labor (number)	2.2 (2.5)	1.0 (1.0)	1.3 (1.0)
Volunteering (number)	1.3 (1.0)	1.0 (5.0)	1.0 (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)	222.0 (22)	253.1 (262.9)	0.0 (0.0)
Use of animal excreta to fertilize crops (h/year)	13.4 (13.8)	19.6 (18.6)	29.8 (18.4)

Table 4. 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.

Pattern 2 (5 farms) was characterized by a moderate use of CLI practices. Animals were fed with both crop products and industrial feed and the farmers carried out partial collection of animal excreta to fertilize the crops. The investment of seasonal family workers was different according to the farms (1 farm using regular family work, 2 farms with occasional or seasonal assistance, and 1 farm without family assistance). The farms using hired labor (2 farms) used on average 0.2 full-time employee. Volunteering was used by one farm, which used five volunteers. Work with animals was delegated to family labor (3 farms) or to employees (2 farms). Pattern 2 counted four ME farms (ME1, ME2, ME3, and ME5) and one MCI farm (MCI3). In Pattern 2, the farms reared more polygastrics than the two other patterns (on average 16.4 TLU of monogastrics and 3.6 TLU of polygastrics) (Table 4). Average animal herd size was 198 head, with on average 2.6 animal species per farm. These farms cultivated the largest sugarcane and pasture area, representing on average 7.7 and 3.6 ha, respectively.
In pattern 3 (3 farms), the farms also made moderate use of CLI practices: the animals are fed with industrial feed but animal excreta are more regularly used to fertilize the crops than in the other patterns. The farms used seasonal family workers. This workforce was regular family work (1 farm) or occasional or seasonal assistance (2 farms). On average, 1.3 seasonal family workers were involved on the farm. This pattern used more hired labor than the other two patterns (2 farms with on average 0.5 full-time employee). Work with animals was delegated to permanent workers (2 farms), family members (2 farms), and volunteers (2 farms). Pattern 3 counted three MCI farms (MCI4, MCI2, and MCI5). Pattern 3 farms had the largest herd size (on average 287 animals) and reared more monogastrics (23.1 TLU) than the other two patterns. On average, 1.7 different animal species were reared on the farm. These farms cultivated the smallest pasture area (1 ha) and the largest area of market gardening (3.7 ha).

Work duration and arduousness

These three patterns had different work durations. Both seasonal and routine work were higher in Pattern 3 (on average 13.8 and 3.8 h/d, respectively) than in Pattern 2 (on average 8.2 and 3.4 h/d, respectively) and Pattern 1 (on average 5.5 and 2.4 h/d, respectively). Routine work efficiency was lower in Patterns 2 and 3 (0.12 h/d/TLU) than in Pattern 1 (0.26 h/d/TLU). Increasing herd size improves the quantity and efficiency of routine work. This increase in efficiency is probably driven more by economies of scale than by the benefits of being able to mechanize since most tasks are manual on these farms. The increase in quantity of routine work does not seem to be compatible with the additional time required to implement CLI practices. In such systems, the use of crop products as animal feed occurs on a daily basis. Like milking in dairy systems, it is the most structured and time-dominant feature of the routine work and can shape work organization on the farm (Cournut *et al.,* 2018). Considering animal feeding, Pattern 2 spent more time using crop-products as animal feed (253.1 h/year) than Pattern 1 (on average 222.0 h/year) probably because of the higher number of animals, whereas farmers in Pattern 3, who have more animals and more routine work, did not perform this practice**.** Farmers of Pattern 3 pointed out 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, my enterprise is industrial-scale, I don't have just 20 rabbits where it is easier."* Consequently, Pattern 3 farms, 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 (on average 29.8 h/year) than those in Pattern 2 (on average 19.6 h/year) and those in Pattern 1 (on average 13.4 h/year) because of the higher number of animals. Using animal excreta to fertilize crops is manual on most farms except

for MCI2 and MCI4, which are intensive pig breeders using a slurry tanker. Manually, this work is considered arduous but technically simple. Extensive animal units (Pattern 1) allowed lower volumes of excreta that can be collected more regularly. These low volumes are consistent with the low area to fertilize (on average 0.9 ha of market gardening in Pattern 1). In Patterns 2 and 3, the farmers preferred to group animal excreta and perform low number of harvest. 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 the first limiting factors in the use of this practice.

In Pattern 1, as in most partly subsistence/partly commercialized farming systems around the world, the use of CLI practices is a way to close the nutrient loop on the farm and the benefits of these practices are mainly related to the decrease in cost by relying on internal inputs rather than on external inputs. In more commercial MCLS (Patterns 2 and 3), the animal diet is improved by using industrial feed based on imported cereals and soya, which question the economic and environmental sustainability of such systems. Moreover, in such commercial MCLS, using CLI practices would induce higher workforce requirements vis-à-vis specialized systems (EIP-AGRI Focus Group, 2017). The lack of knowledge on how to manage CLI practices and the impact of such practices on work organization would impair adoption of these practices (Cortner *et al.,* 2019).

Our research suggests a link among production systems, work organization, and implementation of CLI practices. But this link does not seem absolute and depends on the local context, farm organization, and farmers' motivations (Sneessens *et al.,* 2016). Some farmers by their organization and their strong motivation for the implementation of CLI practices can manage to combine a productive model and a high valorization of crop-products in animal feed (Dieguez *et al.,* 2010). This is even more 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), all the more so if they do not consider working with animals as a constraint.

Animal perceptions and impact on CLI practices

Our study highlighted that farmers' perceptions of work, especially with animals, would also influence the level of implementation of CLI practices. In Pattern 1, with a strong use of CLI practices, the role of animals is mainly relational for farmers. They enjoy working with animals. Their profession gives them job satisfaction, personal growth, and well-being. These farmers performed more CLI practices. Tasks with animals are not fully delegated, as much for the pleasure farmers get out of them as for mistrust in the workforce. Unlike crops, animals require daily attention from experienced stock people, especially for some fragile animals (small monogastric animals and small ruminants). This daily attention from skilled labor allowed the farmers to be abreast of the health status of their animals or to ensure adequate feeding of their animals, 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 limited the adoption of MCLS by farmers. According to these authors, it would appear easier for animal systems to convert into MCLS than crop systems because of the presence of skilled animal breeders.

In Pattern 2, farmers refer much more to the economic rewards of their trade and the economic advantage of both CLI and animals. They mainly identify a role for technical services provided by animals, such as a supplier of organic matter. In Pattern 3, the farmers have productivity objectives because of the choice of intensive and more industrial animal activities. This productivity objective was also reflected in their reference to economic and professional identity rationalities for their profession.

Animals were primarily considered as a source of income within the farm. In this pattern, the farmers prefer feeding animals with industrial feed rather than on-farm crop-products as they consider crop-products to have lower nutritional value and consequently to allow 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." In addition, management of crop-products (collection, transportation, storage, and distribution) appears harder for farmers than with industrial feed.

Levers for the development of crop–livestock integration practices

Several factors such as the presence of infrastructure (buildings and machinery), the presence of different sites of the farms and their remoteness, thieving pressure, trust in employees, and the animal species may influence farmers' use of CLI practices. However, farmers cited the time burden of collecting crop-products and animal excreta as one of the first limiting factors in the use of CLI practices. This section mentions some specific or generic levers that can be operated to improve the implementation of CLI practices by farmers or to stimulate their adoption by farmers who have not adopted them yet. Some of them have already been mentioned for CLI in other contexts or for other agroecological practices.
The low nutritional quality of crop-products would induce too much time in arduous work to collect the animal diet. Mechanized collection of both crop-products and animal excreta appears as an alternative on these small family farms (Patterns 1 and 2), where work is mainly manual and can be physically exacting. However, machinery manufacturers pay little attention to developing special machines for agroecologization and small-scale farming (Dedieu, 2019). Following the agroecological vision, which consists of letting nature do the work, grazing or idle-grazing animals offer the opportunity to make animals directly collect the diet and fertilize the plot with minimum human intervention, allowing a decrease in the purchase of inputs and the cost of labor. Although grazing is widespread in our sample since 11 of the 14 farms surveyed reared ruminants on pasture, this practice seems more adapted to large areas and would find limits in our insular context. Ruminants are much more involved in this practice. Rearing monogastrics outdoors tend to develop-but raises questions, especially about animal welfare since most monogastric breeds have been selected for high performance indoors.
Intensification of labor is the preferred path (rather than investing in equipment and external inputs) for increasing the production of farms – often family farms – around the world and at different time points (Aubron *et al.,* 2016). This goes hand in hand with the creation of agricultural jobs that appear desirable for both developing and industrialized countries to halt rural depopulation and unemployment. If labor is an abundant resource in these countries, the labor code in industrialized countries (also in force in our study area) means that the benefits of CLI related to external input saving would not cover the additional costs associated with employing a new person to do the job. Our point here is not to criticize the labor code in industrialized countries but to propose strategies that would make CLI practices more attractive for farmers.
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, these policies may influence farmers' perceptions of such practices (Cortner *et al.,* 2019). But the lack of data allowing us to objectify the impact of such practices would limit the development of adequate policies and consequently adoption

(Cortner *et al.,* 2019; Garrett *et al.,* 2020). Market governance can consider consumers' requirements around 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 better valorize production and consequently be able to pay an additional employee.
For more commercial farms (Patterns 2 and 3), cooperation at the territorial level allows farmers to share crop-products or skilled labor to collectively support the additional cost, which also represents an alternative to resolve or diminish these workload problems (Moraine *et al.,* 2016; Martin *et al.,* 2016). These include shared employees, task delegation, or shared tasks between farmers as well as shared equipment to increase productivity (Andersson *et al.,* 2005). Nevertheless, this strategy must take into account the local context to propose organizational innovations, social coordination, and public policies to support CLI practices at the territorial level (Moraine *et al.,* 2016).

Methodological considerations

The QuaeWork method allows us to quantify and qualify work organization and assess work productivity and flexibility on farms. In addition to work efficiency, it allows accounting for other dimensions of work organization, such as delegation strategies, management of workload peaks, and livestock management. This method has already been tested in several tropical countries, where it can relate farm practices to work organization (Hostiou and Dedieu, 2012). However, it has been mainly designed for livestock farming systems and practices related to animal management (Cournut *et al.,* 2018). Here, it was applied to 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) allowed us to overcome the time constraint and difficulties involved in asking farmers to inventory all their crop tasks.
Some room for improvement exists, especially when addressing "agroecologization" of agriculture. In this study, we used the conceptual framework of livestock farming systems developed by Gibon *et al.* (1999), which considers the farmer as a driver of the system and the work organizer (Dedieu and Servière, 2012; Cournut *et al.*, 2018). We do not consider the views of employees, volunteers, or family members. Their perceptions of work with animals and CLI practices could bring out additional considerations not noticed by the farmers (Malanski *et al.*, 2019). In the same way, the gender issue is not addressed although women can play an active role in the success of some development programs, especially on smallholder farms (Doss, 2017). Moreover, we focused on farms that already implement CLI practices, assuming that they can bring insights for new farmers. The vision of farmers that do not implement CLI practices would also be interesting, especially with regard to the perception of work with animals, which can differ between crop producers and breeders (Cortner *et al.,* 2019).
The methodology presented here, built on a combination of quantitative and qualitative methods with a conceptual framework of local systems, can be adapted to the very diverse situations with a high level of diversity around the world, including crop systems (Delecourt *et al.,* 2019) or other MCLS.

Conclusion

Here, we adapted the QuaeWork method for MCLS farms to study the relationship between CLI and work organization. Three patterns of contributions of CLI to work organization were observed. These patterns opposed family-run farms oriented toward high-level implementation of CLI practices against intensive farms oriented toward high animal productivity. The availability of family workforce and trust in the workers who have to manage the animals are two factors that play a central role in family farms, whereas the management of the low nutritional value of crop by-products appears to be a barrier to the development of CLI on more intensive farms. Adapted motorization and short training courses would allow overcoming the technical limits, while higher-level regional-scale political changes are needed to reorient the marketing chain toward valorization of the higher quality provided by local feed. This work quantifies and understands the relationship between CLI practices and work characteristics of the farm. It can be used to support discussion with farmers that have not already developed MCLS.

References

Andersson H., Larsen K., Lagerkvist C.J., Andersson C, Blad F., Samuelsson J., Skargren P., 2005. Farm cooperation to improve sustainability, *Ambio* 34, 383–387, doi:10.1639/0044-7447(2005)034[0383:FCTIS]2.0.CO;2.

Aubron C., Noel L., Lasseur J., 2016. Labor as a driver of changes in herd feeding patterns: Evidence from a diachronic approach in Mediterranean France and lessons for agroecology, *Ecological Economics* 127, 68-79, doi:10.1016/j.ecolecon.2016.02.013.

Bell L.W., Moore A.D., 2012. Integrated crop–livestock systems in Australian agriculture: Trends, driversand implications, *Agricultural Systems* 111, 1-12, doi:10.1016/j.agsy.2012.04.003.

Bendahan A.B., Poccard-Chapuis R., de Medeiros R.D., Costa N.D., Tourrand J.F., 2018. Management and labour in an integrated crop-livestock-forestry system in Roraima, Brazilian Amazonia, *Cahiers Agricultures* 27, doi:2500510.1051/cagri/2018014.

Bertin J. (Eds), 1977. *La graphique et le traitement graphique de l'information,* Paris, Flammarion Paris.

Coquil X., Cerf M., Auricoste C., Joannon A., Barcellini F., Cayre P., Chizallet M., Dedieu B., Hostiou N., Hellec F., Lusson J.M., Orly P., Prost L., 2018. Questioning the work of farmers, advisors, teachers and researchers in agro-ecological transition. A review, *Agronomy for Sustainable Development* 38, doi:0.1007/s13593-018-0524-4.

Cortner O., Garrett R.D., Valentim J.F., Ferreira J., Niles M.T., Reis J., Gil J., 2019. Perceptions of integrated crop-livestock systems for sustainable intensification in the Brazilian Amazon, *Land Use Policy* 82, 841-853, doi:10.1016/j.landusepol.2019.01.006.

Cournut S., Chauvat S., Correa P., Dos Santos J.C., Dieguez F., Hostiou N., Pham D.K., Serviere G., Srairi M.T., Turlot A., Dedieu B., 2018. Analyzing work organization on livestock farm by the Work Assessment Method, *Agronomy for Sustainable Development* 38, doi:5810.1007/s13593-018-0534-2.

Dedieu B., 2019. Transversal views on work in agriculture; *Cahiers Agricultures* 28, 8(9). doi:https://doi.org/10.1051/cagri/2019008.

Dedieu B., Serviere G., 2012. Twenty years of research and development on work in livestock farming: achievements and prospects, *Inra Productions Animales* 25, 85-99.

Delecourt E., Joannon A., Meynard J.M., 2019. Work-related information needed by farmers for changing to sustainable cropping practices, *Agronomy for Sustainable Development* 39, doi:2810.1007/s13593-019-0571-5.

Dieguez F., Morales H., Cournut S., 2010. The work assessment method for a functional approach to extensive Uruguayan beef farms, *Cahiers Agricultures* 19, 316-322, doi: 10.1684/agr.2010.0419.

Doss C., 2017. Women and agricultural productivity: Reframing the issues, *Development Policy Review* 36, 35-50, doi:10.1111/dpr.12243

EIP-AGRI Focus Group, 2017. *Mixed Farming Systems*, livestock/cash Crops.

Fanchone A., Alexandre G., Chia E., Diman J.L., Ozier-Lafontaine H., Angeon V., 2020. A typology to understand the diversity of strategies of implementation of agroecological practices in the French West Indies, *European Journal of Agronomy* 117, doi:10.1016/j.eja.2020.126058.

Fiorelli C., Mouret S., Porcher J., 2012. Rationalities for working with animals: producing, living together and self-fulfilling, *Inra Productions Animales* 25, 181-192.

Garrett R.D., Ryschawy J., Bell L.W., Cortner O., Ferreira J., Garik A.V.N., Gil J.D.B., Klerkx L., Moraine M., Peterson C.A., dos Reis J.C., Valentim J.F. 2020. Drivers of decoupling and recoupling of crop and livestock systems at farm and territorial scales, *Ecology and Society* 25(1), 24, doi:10.5751/ES-11412-250124.

Gibon A,. Sibbald A.R., Flamant J.C., Lhoste P., Revilla R., Rubino R., Sorensen J.T. 1999. Livestock farming systems research in Europe andits potential contribution for managing towards sustainability inlivestock farming, *Livestock Production Science* 96, 11-31, doi:10.1016/S0301-6226(99)00062-7.

Herrero M., Thornton P.K., Notenbaert A.M., Wood S., Msangi S., Freeman H.A., Bossio D., Dixon J., Peters M., van de Steeg J., Lynam J., Rao P.P., Macmillan S., Gerard B., McDermott J., Sere C., Rosegrant M., 2010. Smart Investments in Sustainable Food Production: Revisiting Mixed Crop-Livestock Systems,. *Science* 327, 822-825, doi:10.1126/science.1183725.

Hostiou N., Dedieu B., 2012. A method for assessing work productivity and flexibility in livestock farms, *Animal* 6, 852-862, doi:10.1017/s1751731111002084

Madelrieux S., Dedieu B., 2008. Qualification and assessment of work organisation in livestock farms, *Animal* 2, 435-446, doi:10.1017/s175173110700122x

Malanski P., Ingrand S., Hostiou N., 2019. A new framework to analyze changes in work organization for permanent employees on livestock farms, *Agronomy for Sustainable Development* 39 (1), 1-12, doi:10.1007/s13593-019-0557-3.

Martin G., Moraine M., Ryschawy J., Magne M.A., Asai M., Sarthou J.P., Duru, M., Therond, O., 2016. Crop-livestock integration beyond the farm level: a review, *Agronomy for Sustainable Development* 36. doi:10.1007/s13593-016-0390-x.

Moraine M., Grimaldi J., Murgue C., Duru M., Therond O., 2016. Co-design and assessment of cropping systems for developing crop-livestock integration at the territory level, *Agricultural Systems* 147, 87-97. doi:10.1016/j.agsy.2016.06.002.

Ryschawy J., Choisis N., Choisis J.P., Joannon A., Gibon A., 2012. Mixed crop-livestock systems: an economic and environmental-friendly way of farming?, *Animal* 6, 1722-1730. doi:10.1017/s1751731112000675.

Sneessens I., Veysset P., Benoit M., Lamadon A., Brunschwig G., 2016. Direct and indirect impacts of crop-livestock organization on mixed crop-livestock systems sustainability: a model-based study, *Animal* 10, 1911-1922, doi:10.1017/s1751731116000720.

Stark F., Fanchone A., Semjen I., Moulin C.H., Archimede, H. 2016. Crop-livestock integration, from single-practice to global functioning in the tropics: Case studies in Guadeloupe, *European Journal of Agronomy* 80, 9-20, doi:10.1016/j.eja.2016.06.004.

Timmermann C., Felix G.F., 2015. Agroecology as a vehicle for contributive justice, *Agriculture and Human Values* 32, 523-538. doi:10.1007/s10460-014-9581-8.

Wezel A., Casagrande M., Celette F., Vian J.F., Ferrer A., Peigne J., 2014. Agroecological practices for sustainable agriculture. A review, *Agronomy for Sustainable Development* 34(1),1–20, doi: 10.1007/s13593-013-0180-7.