INTERCROP VALUES

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D1.2
Characteristics of collective organizations and conditions to boost intercropping in the EU



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Abstract

This deliverable presents the cross-analysis of the results from three studies exploring a new field of research: **the use and design of agricultural equipment for intercropping practices, and the collective organisations supporting these processes**. This work, conducted jointly by researchers from INRAE and ENSFEA and staff from FNCUMA[1], addresses **3 complementary questions analysed by 3 studies**: (i) What logics guide farmers' use of agricultural equipment when implementing intercropping practices? (ii) How do farmers design and adapt their agricultural equipment fleets as their intercropping practices evolve? (iii) How do farmers use sorting systems to grow and valorise intercropped grains intended for human consumption?

The deliverable presents key findings from the three studies:

Study 1 on logics of farmers' equipment management for intercropping. Six categories of intercropping, which differ in terms of how they are managed and in the characteristics that farmers consider when choosing and using agricultural equipment, as well as three logics underlying farmers' equipment management for intercropping (e.g. choosing intercrops and agricultural equipment based on locally available resources).

Study 2 on farmers' trajectories in designing and adapting their machinery fleets over the long term. A range of activities undertaken by farmers when designing their equipment fleets along their intercropping trajectories (e.g. self-construction and repurposing of equipment), as well as three design logics for agricultural machinery fleets over the long term (eg. frugal equipment-fleet design to develop intercropping).

Study 3 on grain cleaning and sorting equipment from the perspective of collective organisations among farmers. An overview of six contrasting sorting systems (e.g. a CUMA-based sorting line for the final cleaning of a crop, with a manager coordinating the sorting processes), as well as three ideal-type rationales for using sorting systems to produce and valorise intercropped crops for human consumption (e.g. the sorting system as the cornerstone of the production and valorisation of a crop with high social or heritage value).

This document shows that **collective arrangements are most frequent for sorting and sowing, and that they provide farmers with skills and shared know-how as well as access to equipment**. It concludes by drawing general lessons and outlining perspectives: (i) on the value of documenting agricultural equipment uses to engage with stakeholders involved in transforming the agricultural sector, (ii) to support the on-farm design and appropriation of equipment for implementing intercropping, (iii) to foster collective dynamics among farmers that drive the appropriation and design of equipment, and (iv) to enrich agronomic perspectives on intercropping by considering agricultural equipment uses.

[1] FNCUMA is the national federation of CUMAs in France.

1. SCOPE OF THE STUDY AND RESEARCH QUESTIONS

1.1 Scope of the study: equipment uses and collective dynamics

Discussing collective organisation to support the development of intercropping is a broad topic. At the outset of the IntercropVALUES project, through discussions among researchers from INRAE and ENSFEA and staff from the National Federation of Agricultural Machinery Cooperatives (FNCUMA[2]), we narrowed the focus of our work to the issue of farm machinery for intercropping, and the collective organisations that support its use and design.

This research topic was selected for several reasons: (i) It was identified during the design of the IntercropVALUES project as a topic worth investigating to support the development of intercropping in Europe (WP3), (ii) the use of farm machinery to develop agroecological or sustainable farming practices is currently an emerging research topic that remains largely unexplored in agronomy, and (iii) the CUMA network, whose main role is to support the emergence and development of farmer cooperatives organised around the collective use of equipment, highlighted the strategic importance of addressing this issue and bringing it into its network of about 10,000 CUMA across France.

To explore this research topic, we pooled our resources between Task 1.2 and Task 3.4, with the aim of conducting three complementary studies over the course of the IntercropVALUES project. Since research on the use of farm machinery is still very limited, we started conducting studies at the individual level (interviewing farmers individually about their practices of intercropping), with the aim of gaining a better understanding of our research object and identifying issues of interest to investigate further in relation to its collective dimensions. The first two studies focused respectively on: (i) the logics of farmers' equipment management for intercropping during a cropping season (E. Fouillet's postdoctoral research), and (ii) farmers' trajectories in designing and developing their machinery fleets over the longer term as they implemented intercropping practices (H. Pham's internship). The third study explored in greater depth the issue of grain cleaning and sorting equipment, which had emerged as a key issue in the previous studies, by examining it from the perspective of collective organisations among farmers that support the implementation of these activities (L. Bodey's internship). Across all three studies, we focused on the practice of intercropping involving at least one specie intended for use as human food.

The results from these three studies are diverse. In this deliverable, we focus on those that provide insights into the dynamics of collective organisation around the use and design of equipment for intercropping practices. The results presented here compile

[2] A CUMA (Cooperative for the Use of Agricultural Equipment) is a type of cooperative in which several farmers join forces to purchase, share, and maintain agricultural equipment, buildings, or labor.

excerpts from more extended reports and articles on each study (Fouillet et al., 2026; Pham, 2024; Bodey, 2026).

This deliverable D1.2 is complementary to the deliverable D3.2[3], which presents in detail innovative equipment developed by farmers and six categories of intercrops, three equipment management logics and three equipment-fleet design logics. To avoid duplication, these results are only summarised here (Sections 3.1 and 3.2) and re-read through the lens of collective organisation. The results on sorting systems (Section 3.3) and the cross-analysis (Section 4) are specific to this deliverable D1.2.

All three studies supporting this D1.2 were conducted in France, where the CUMA network offers a particularly rich field for studying collective organisations around agricultural equipment. As explained in D3.2, the partner that was initially expected to cover a second country (SRUC, Scotland) could not contribute to this work (lack of UK grants for doing the work). The extrapolation of the findings and the conditions to boost intercropping in EU to ensure wider dissemination beyond the consortium are discussed in Section 5.

1.2 The relevance of studying equipment use for intercropping

Despite the well-known agronomic, environmental, and economic benefits of intercropping[4], farmers wishing to implement this practice may face various challenges[5]. One of these concerns the practical implementation of intercropping, and the possibility of accessing and using adapted equipment (Verret et al., 2020). The technical issues are diverse:

- **Sowing intercrops** can be complicated by differences in seed size or sowing depth, raising questions about sowing methods and adapted machinery that can support agronomically beneficial processes while taking into account the physiology of the different species (Ratnadass et al., 2012).
- **Harvesting intercrops** may be constrained by the non-synchronous maturity of species, resulting in yield losses or quality issues (Lemken et al., 2017) and differences in seed characteristics between crops can make harvester settings more challenging.
- **Post-harvest sorting of mixed grains**, which requires specific equipment or additional labour, can affect the marketability of the final product, especially when intended for human consumption (Meynard et al., 2018; Verret et al., 2020).

The implementation of intercropping can also be hampered by a lack of tailored technical advice and local knowledge (Bonke et al., 2021), and by limited access to

[3] Practical guides and videos presenting innovative machineries designed or adapted by farmers related to sowing, mechanical weeding, harvesting, cleaning and sorting, and dissemination of operational solutions
[4] See e.g.: Bedoussac & Justes, 2010; Bedoussac et al., 2015; Raseduzzaman & Jensen, 2017; Li et al., 2023; Hauggaard-Nielsen et al., 2008; Yan et al., 2024
[5] See e.g.: Meynard et al., 2018; Bonke et al., 2021; Mamine & Farès, 2020; Aare et al., 2021; Verret et al., 2020

adapted value chains or unclear market outlets for mixed products (Mamine and Farès, 2020).

While some farmers are already growing intercrops (e.g. Aare et al., 2021; Verret et al., 2020), little is known about how they manage agricultural equipment to implement this practice in relation to their specific situations (e.g. farm history, soil types, farmers' projects, locally available equipment). Although the findings presented in D3.2 show that farmers did not perceive equipment as an obstacle to starting, or a reason for abandoning intercropping, it remains essential to understand the collective dynamics on which they rely to cultivate intercrops, in order to support the development of this practice.

1.3 Research questions

Given the exploratory nature of this research, we investigated, through three complementary studies over the course of the IntercropVALUES project, the following questions:

1. **What logics guide farmers' use of agricultural equipment when implementing intercropping practices? (Study 1; E. Fouillet's postdoctoral)**

Following the tracking farmers' innovations approach, this study aimed to explore how farmers described the ways in which they chose to access and use different types of equipment to manage intercropping in ways that were consistent with their projects and working situations.

2. **How do farmers design and adapt their agricultural equipment fleets as their intercropping practices evolve? (Study 2; H. Pham's internship)**

Through a longitudinal study, this research aimed to explore how farmers redesign simultaneously their intercropping practices and their equipment fleets over time.

3. **How do farmers use sorting systems to grow and value intercrops intended for human consumption? (Study 3; L. Bodey's internship)**

Through a study of a panel of cases involving groups of farmers sharing access to sorting equipment, this study aimed to characterise this practice and identify variations in how it is implemented.

All these three studies were based on the assumption that there are diverse ways of managing equipment in order to implement intercropping, and that investigating this diversity could provide insights into how to support change, as well as inform discussions about the future design of equipment adapted to intercropping practices. In addition to these three questions, a cross-cutting question guided the cross-analysis presented in Section 4 of this deliverable, namely: how do formal and informal collective organisations support farmers access to equipment for intercropping, its use and design?

2. METHOD: THREE COMPLEMENTARY APPROACHES

The three studies conducted between 2023 and 2026 are case studies and fall within the field of practice-oriented research in agronomy. They are based on comprehensive approaches. Each study was designed and conducted in close collaboration between researchers from INRAE and ENSFEA and staff from FNCUMA, with the aim of facilitating the uptake of the results both within academic and agricultural development communities.

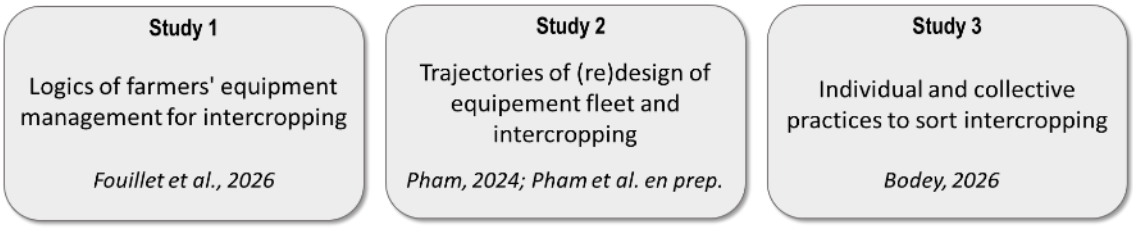


Figure 1. Three complementary studies implemented during the IntercropVALUES project

The first study focused on a panel of cases involving farmers implementing intercropping using a range of agricultural equipment (Fouillet et al., 2026). This study drew on the tracking farmers' innovations approach (Salembier et al., 2021). In total, 13 farmers were interviewed across France in 2023. For each case, we analysed farmers' practices when they implemented one or more intercrops during the 2022 cropping season. The study involved characterising their crop management practices, the agricultural equipment they used from sowing to sorting, and their logics of action.

The second study aimed to analyse how farmers practise intercropping over the long term, and how they design and adapt their equipment fleets accordingly (Pham, 2024; Pham et al., in prep.). This study drew on research into processes of practice change and design processes (e.g. Revoyron et al., 2022; Salembier et al., 2021). Sixteen farmers were interviewed across France in 2024, covering trajectories of practice change over periods ranging from 3 to 40 years.

The third study focused on collective grain-sorting initiatives (Bodey, 2026). Drawing on research into farming practices in agronomy (Gras et al., 1989), the study aimed to characterise variations in how sorting activities are carried out collectively by several farmers, the equipment used, and the organisational arrangements involved, as well as the logics reported by participants. In addition to interviewing farmers who grew and sorted their intercrops, this research required interviews with representatives and/or employees of the collective organisations studied. In total, seven collective grain-sorting initiatives were investigated (nine farmers and one employee interviewed).

Data were collected through semi-structured interviews, complemented by observations of agricultural equipment and fields. Each interview was fully transcribed and coded, and a case narrative was produced for each case, adapted to the specific research question addressed. A cross-case analysis then led to the

identification of ideal types, making it possible to generalise the findings at a higher level of abstraction (e.g. ideal types of rationales for managing agricultural equipment for intercropping).

These studies are exploratory and rely on small samples (13 and 16 farmers for the first two studies, seven sorting initiatives for the third). Across the three studies, farmers were identified through the CUMA network, social media, the agricultural press, contacting development network agents including advisors, and using snowball sampling among farmers. All cases are located in France, and we discuss the interests of the results to other European contexts.

3. RESULTS

3.1 Logics of farmers' equipment management for intercropping

In the first study (Fouillet et al., 2026), the cross-case analysis made it possible to identify **six categories of intercrops** (among 21 intercrops studied, Figure 2), which differ in relation to how they are managed, and the characteristics that farmers consider in their choice and use of agricultural equipment (e.g. sowing depth appeared as a key characteristic at the interface between equipment choice and the management of crop mixtures).

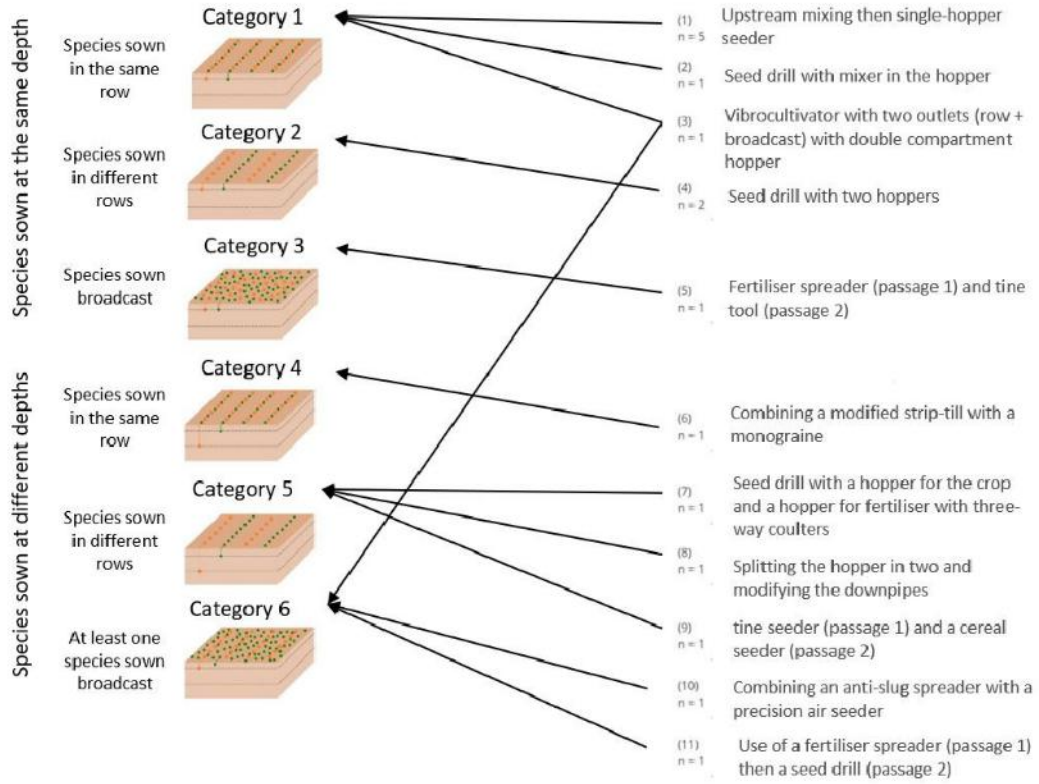


Figure 2: Schematic representation of the six categories of intercrops identified according to seeding depth and spatial arrangement of associated species (Left); Equipment and number of farmers using them (n=) for the different intercrop categories (Right) (Figure extracted from Fouillet et al., 2026)

These categories have been used when characterising three ideal types of agricultural equipment fleet management logics for intercropping. These are described below (extract from Fouillet et al., 2026), and Table 1 presents the three ideal types we drew (see D3.2, Section 1.3 for details). Each farmer in our sample (13 farmers interviewed) refers to one ideal type of management logic.

- **Logic 1: Minimising mechanisation costs by using the agricultural equipment already present on the farm**

Four farmers have practices related to this management logic: mobilising a large fleet of old agricultural equipment to minimise costs. On the one hand, this allows them to grow a diversity of mixtures (2 to 5) during most of their crop succession but, on the other, they have to adapt the spatial arrangement of the intercrops (1 to 3 categories, Figure 2) according to the available equipment's technical possibilities, just as they adapt their harvesting and sorting practices according to the outlets available to them (see D3.2 for details). In this logic, collective arrangements between farmers plays a limited role since the equipment used is mainly owned by the farmer.

- **Logic 2: Sowing intercrops according to the characteristics of the species by adapting agricultural equipment**

Six farmers have practices related to this management logic: adapting farm equipment to the services expected from the intercrop. To this end, they repurposed, modified or purchased one or more agricultural equipment items, enabling them to cultivate 1 to 5 intercrops and to adapt the sowing and spatial arrangement either to the physiology of the species or for specific services (1 or 2 categories), while minimising the number of runs (see D3.2 for details). Although equipment is owned individually, its adaptation may rely on informal cooperation (e.g. mechanical skills of one fellow farmer have led one farmer to customize a no-till seed drill) and to adapt the combine's settings to limit grain breakage.

- **Logic 3: Choosing intercrops and agricultural equipment based on locally available resources**

Three farmers have practices related to this management logic, which involves adapting intercrops to the year's context, using a wide range of locally available agricultural equipment (co-ownership, contractors and CUMA). These three stood out, as they grow a more diverse array of intercrops (1 to 6). Their crop successions also vary from year to year, as their choice is not constrained by potential harvesting or sorting difficulties, given the diversity of agricultural equipment available to them. It should be noted that these three farmers worked in the same region and used the same sorting farm, a key driver in crop diversification and the development of intercropping (see D3.2 for details). For example, one farmer grows eight intercrops, sown with his own single-hopper seeder or with a repurposed fertiliser spreader. Harvesting is carried out by a farm contractor who owns several types of combine harvesters. The intercrops are then sorted at the sorting farm he has set up with other farmers, which is equipped with a complete sorting chain, from cleaner-separator to optical sorter. This service allows this farmer not only to limit his investments in agricultural equipment, but also to gain access to a wide range of techniques for growing a variety of intercrops, some of which he can sell directly. As he explained: '*There are two reasons why I'm able to make these mixtures. It's because the contractor is equipped to harvest whatever I sow, and then, after that, because the sorting farm is equipped to unmix whatever I bring in*'.

Action logics	Key elements of the farmer's situation	Intercrops					Agricultural equipment fleet	
		Nb of species / Nb of intercrop categories	**Choice of spatial arrangement**	**Harvesting equipment**	**Sorting equipment**	**Integration into the crop succession**	**Type of modification to agricultural equipment for intercrop management**	**Adaptability of combinations and/or agricultural equipment**
1. Minimising mechanisation costs by using the agricultural equipment already available on the farm	A large and often ageing stock of agricultural equipment	1 to 5 / 1 to 3	To make the most of the agricultural equipment already present on the farm and to respect the physiology of the species	Owned by the farmer	Owned by the farmer or sorting outsourced	Fixed succession	Repurposing / Combination / Modification of physical structure	Adaptable species mixtures
2. Sowing intercrops according to the characteristics of the species by adapting agricultural equipment	variable investment capacity / DIY skills and knowledge of agricultural equipment	1 to 5 / 1 or 2	Goal-oriented (*e.g.* respecting the physiology of species or fostering a barrier effect)	Owned by the farmer	Owned by the farmer or sorting outsourced	Semi-fixed succession: various degrees of flexibility, adjustments according to weed prevalence on the fields	Purchase / Modification of physical structure / Self-build	Adaptable intercrops and agricultural equipment for single crop and species mixtures cultivation
3. Choosing intercropped species and agricultural equipment based on available resources	Presence of a farm contractor in the area / Changing mixtures year on year	2 to 6 / 1 or 2	Profitability and other farmer-specific goals	Owned by the farmer or harvest outsourced	Owned by the farmer or a group or sorting outsourced	No fixed succession, with decisions based on field conditions (weeds), the market and the economic interest of the crops	Repurposing / contractors	Adaptable agricultural equipment

Table 1: descriptive variables used to characterise the ideal types of agricultural equipment management logics. These variables concern: (i) the farmer's situation, (ii) intercrops (number of mixtures grown, number of categories, choice of spatial arrangement, harvesting, sorting and integration into the crop rotation), and (iii) their agricultural equipment fleet (types of modification for intercrop management and adaptability of intercrops and/or agricultural equipment) (extracted from Fouillet et al., 2026)

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3.2 Three logics for designing agricultural machinery fleets along farmers' intercropping trajectories

The second study (Pham, 2024) first made it possible to describe a diversity of activities through which farmers design and adapt equipment and machinery fleets to implement intercropping. These activities are presented in Figure 3.

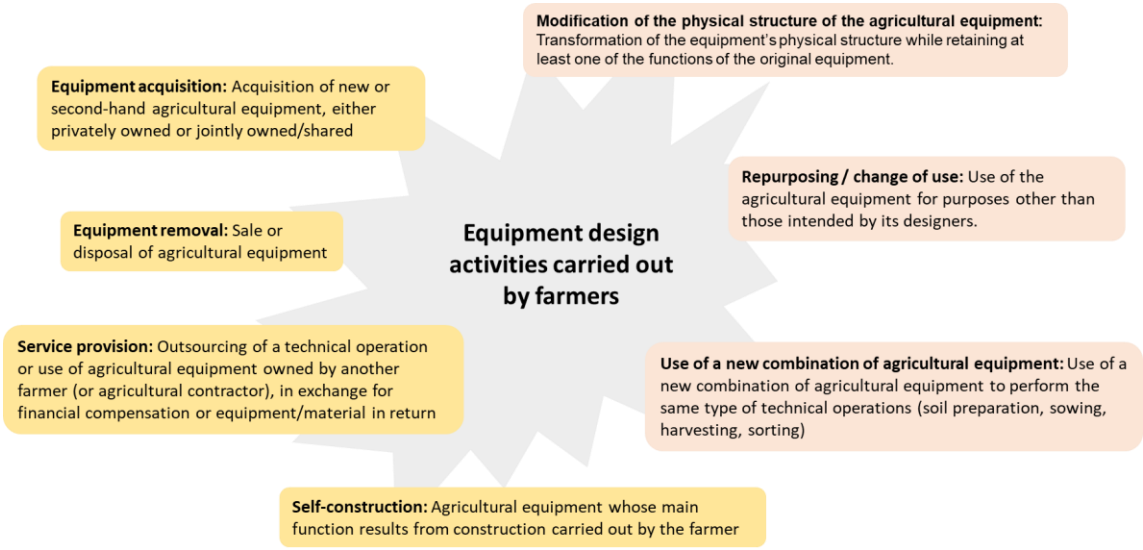


Figure 3. Diversity of activities through which farmers design and adapt equipment to implement intercropping. In yellow, activities related to the design of equipment fleets; in pink, activities related to equipment design.

Building on these initial findings and by analysing the trajectories of each farmer (e.g. Figure 4), this research also revealed several design logics for agricultural machinery fleets for intercropping.

Figure 4 illustrates, at farm level, the co-evolution of the agricultural equipment fleet, intercrops, and dimensions of the farmer's action situation, based on an extract of a farmer's trajectory studied by Pham (2024). In year N, the farmer establishes two intercrops. The wheat–clover mixture, learned about during a cover-crop training course, addresses the difficulty of establishing a cover crop after wheat harvest. It is sown asynchronously using the equipment available on the farm: a single-hopper row seeder for wheat, a fertiliser spreader repurposed for clover, followed by a tine harrow for covering the seeds. The lentil–camelina mixture, introduced to take advantage of camelina's support effect, combines the farm's row seeder for lentils with a neighbour's broadcast seeder for camelina, whose seeds are smaller. Sorting is initially outsourced, but generates significant logistical costs. In N+1, the farmer invests in a complete sorting line, making it possible to bring sorting in-house and to develop direct sales, sorting services, and sales to processors. This investment also supports the introduction of intercrops in which both species are suitable for human consumption, such as lentil–barley (N+1), followed by chia–mung bean (N+2). The latter becomes possible through the acquisition of an APV seeder in N+2, enabling small

seeds to be sown at a high work rate, and through the sorting line equipped with an optical sorter, allowing the two species to be separated and marketed separately.

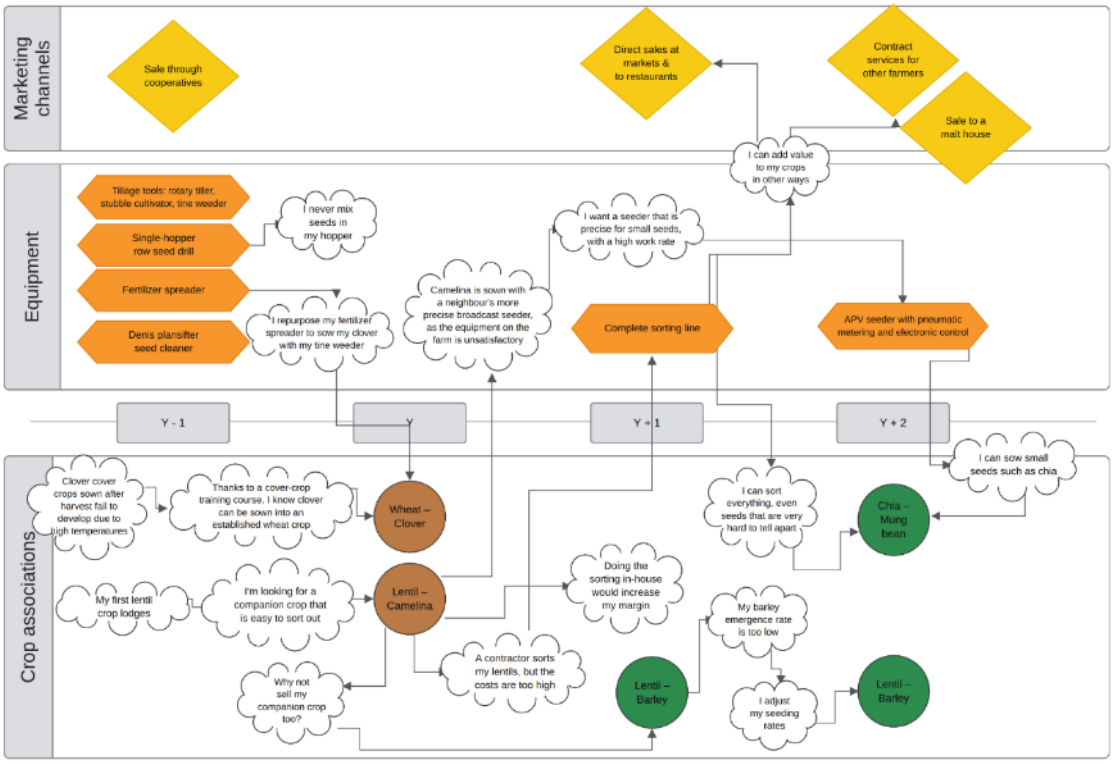


Figure 4: Equipment-fleet design trajectory during the process of implementing intercrop practices on a farm. The trajectory is represented along three interdependent dimensions: (i) the evolution of intercrops and their management, shown at the bottom of the figure and described through the different technical operations, distinguished by a colour code (green = cash-crop intercrops; brown = cash-crop and service-crop intercrops), together with elements of the farmers' logics underlying these practices, represented by clouds, (ii) the agricultural equipment fleet, shown in the centre (orange diamonds), referring to the equipment used for sowing, harvesting, and sorting to manage species mixtures, together with elements of the logics associated with changes in the equipment fleet (represented by clouds), and (iii) elements of the action situation, shown at the top of the figure in yellow (figure adapted from Pham, 2024).

Based on interviews with 16 farmers, Pham (2024) identifies contrasting equipment-design trajectories as farmers implement intercrop practices in arable farming and the cross-case analysis distinguishes three design logics:

- **Frugal equipment-fleet design for developing intercrops (7 farmers)**

In these situations, farmers develop intercrops by seeking low-cost solutions focused on the essential functions of sowing and sorting, relying primarily on reconfiguring existing equipment (repurposing equipment, modifying its physical structure, and combining tools). When investment is necessary, it is constrained through the purchase of second-hand equipment, shared ownership or collective purchasing (CUMA, collective purchasing schemes, GIE), or targeted use of contracting services.

- **Standardised design for large-scale production of a range of intercrops (4 farmers)**

Farmers adapt their agricultural equipment fleets closely to the evolution of new cropping practices, based on substantial investments to produce and process intercrops at large scale, particularly intercrops that are subsequently harvested and sorted. Farmers build up substantial sorting facilities and acquire specialised seeders (often new, with large working widths, frequently equipped with multiple hoppers and sometimes customised) in order to adapt their equipment to changes in their action situation. Contracting services remain secondary, as the main objective is to increase the farm's capacity and autonomy, in a context where outlets are predominantly oriented towards high-volume supply chains.

- **Flexible equipment-fleet design for practising a diversity of intercrops (5 farmers)**

In these trajectories, farmers seek flexibility in their equipment fleets in order to manage an increasing diversity of intercrops. This involves the gradual development of a sorting facility, which, from their perspective, strengthens farm autonomy and supports more integrated valorisation strategies, while occasionally relying on contracting services. They also redesign sowing equipment based on existing resources (repurposing, modifications, and combinations), supplemented to a limited extent by purchasing, self-building, or sharing equipment.

Across these three logics, collective arrangements play contrasting roles: (i) they are central to frugal design (e.g. shared ownership, CUMA, collective purchasing schemes, GIE, targeted use of contracting services), (ii) secondary in standardised design, where farmers seek capacity and autonomy through individual investment, and (iii) on-demand in flexible design (e.g. occasional contracting and equipment sharing).

3.3 Organising collectively to sort grains from intercrops

3.3.1 An overview of six contrasting sorting systems

The third study (Bodey, 2026) proposed a definition to characterise a sorting system[6]. This definition was used to characterise and organise the sorting systems studied into six categories:

[6] In this study, a sorting system refers to '*The relationships between: (i) material dimensions and agricultural equipment (e.g. technical characteristics, location, ownership, functions), (ii) dimensions of use, referring to the processes that the equipment makes possible (i.e., the actions that make up the sorting process, and the ways and conditions in which they are implemented), and (iii) organisational dimensions (i.e., the economic model, stakeholders, organisation of work, mobility and storage of equipment, and the rationale underlying this organisation). These relationships between the three components ('agricultural equipment, processes, and organisation') are embedded in a particular 'action situation'.* (Bodey, 2026)

- **Sorting system 1: CUMA-based sorting line for final cleaning of a crop, with a manager coordinating the sorting processes**

This sorting system is used by four farmers. This system comprises at least two sorting machines, including an optical sorter. The optical sorter uses a camera system and targeted air jets to eject impurities that differ in colour from the crop (Figure 5). In some cases, it is preceded by a flat-screen grader, a sizing machine, an indented-cylinder separator, a gravity table (Figure 5), or a stone separator, which sort the grains according to size or density in order to remove impurities from the crops.

These pieces of agricultural equipment are installed as stationary units in a building belonging either to the sorting manager or to the CUMA. They may be installed in a cascade, i.e. connected to one another so that the different sorting stages are carried out sequentially (non-optical sorting machines in two cases), or they may be operated separately (one case) while the optical sorter is installed separately (two cases). All of these pieces of agricultural equipment are shared under the CUMA status.

This sorting system makes it possible to remove impurities that differ in colour from the main crops (e.g. stained grains and weed seeds of similar size and density). In some cases, it also makes it possible to separate species and to remove impurities differing in density and size, such as broken grains, bruchid-damaged or empty grains, weed seeds, clods of soil, and stones, by adjusting the choice of screens and mantles and the settings of the sorting machines. In all the equipment, an aspiration system removes light waste (e.g. straw and husks) and dust.

In three cases, sorting skills are centralised in a single operator who carries out the sorting for all members. According to some farmers, this centralisation of skills is necessary because it is mainly through sorting experience that these skills are acquired. The sorting fee charged by the CUMA includes remuneration for both the equipment and labour. Equipment costs are calculated according to the volume of grain to be sorted or according to the area committed, sometimes with an additional fixed fee. Members arrange a date with the sorting managers to deliver the batches to be sorted, thereby facilitating the logistics and storage of all the batches awaiting sorting. The sorting operator organises the sorting of the batches as they see fit and informs the member when the batches are ready for collection. The operator can adapt their organisation according to the members' needs or the species being sorted.

- **Sorting system 2: Privately owned stationary sorter for removing some impurities and separating intercropped grains**

This sorting system is used by five farmers. This system systematically includes a screen grader (rotary or flat-screen – Figure 5), which sorts the grains according to size and separates the intercropped species. This piece of agricultural equipment is installed as a stationary unit in a farm building and is privately owned by the farmer. This sorting system makes it possible to remove impurities that differ in size from the main crops (e.g. broken grains, weed seeds, clods of soil, and stones) and to separate intercropped species by selecting the appropriate screens. These graders are most often equipped with an aspiration system to remove light impurities (e.g. straw and

husks) and dust. The farmer carries out the sorting themselves on their farm, and owning a sorter provides them with unrestricted access to the equipment whenever needed.



Figure 5: Mobile rotary sorter with five screens (two photographs at the top); stationary flat-screen sorter with two screens (bottom left); gravity table (bottom centre); optical sorter (bottom right) (photo credit: L. Bodey).

- **Sorting system 3: Mobile CUMA-based sorter(s) for removing some impurities and separating intercropped grains**

This sorting system is used by six farmers. This system comprises one or two sorting machines: systematically, a rotary screen grader for sorting grains according to size (Figure 5), and, in some cases, an indented-cylinder separator for sorting grains according to shape. These pieces of agricultural equipment are mobile because they are mounted on a trailer, either supplied by the manufacturer or purchased separately. All of them are shared under the CUMA cooperative status.

This sorting system makes it possible to remove impurities that differ in size from the main crops (e.g. broken grains, weed seeds, clods of soil, and stones) and to separate intercropped species by selecting the appropriate screens or mantles. In all the equipment, an aspiration system removes light waste (e.g. straw and husks) and dust.

Regarding the collective organisation, in five cases, each member carries out the sorting themselves by hosting the equipment on their own farm.

The sorting fee charged by the CUMA covers the use of the equipment and is calculated according to the area committed, the volume sorted, or the duration of use. Setting up the sorter is often time-consuming and requires considerable space, so some members coordinate with one another and carry out sorting on other members' farms. The equipment is stored at the farm of the last member to use it. This member is responsible for cleaning it with a compressor after use, and the next member who needs it collects it directly from the previous user. In one case, the organisation is slightly different because there are few users: most often, the sorting manager transports the equipment directly to the members' farms.

- **Sorting system 4: Private sorting line for providing a final cleaning service for a single crop**

This sorting system is used by two farmers. This system comprises several sorting machines, including an optical sorter, which is essential for sorting grains according to colour, and, in some cases, other sorting machines such as a flat-screen grader, a gravity table, a stone separator, and an indented-cylinder separator, which sort the grains according to their shape, size, or density. These pieces of agricultural equipment are privately owned, and their installation and operation are managed as part of the company's activities. The crops have already been separated, and grains from a single crop are delivered for sorting. They are either brought to the company by the farmer or collected by truck directly from the farm.

- **Sorting system 5: Stationary sorter(s) on a farm for carrying out final cleaning of a single crop for many farms**

This sorting system is used by four farmers. This system comprises one or two sorting machines, including an indented-cylinder separator, a gravity chute, an optical sorter, an air separator, or a gravity table. These pieces of agricultural equipment are installed as stationary units in a farm building and are privately owned by the farmer, or occasionally jointly owned (indented-cylinder separator, in one case).

These machines are specifically used to sort small volumes because they are not used to separate crop species, but only to remove impurities that differ in shape, such as weed seeds (indented-cylinder separator, in two cases), in density, such as empty or bruchid-damaged grains (gravity chute, air separator or gravity table), or in colour, such as stained grains (optical sorter). With the exception of the gravity chute, these pieces of agricultural equipment are equipped with an aspiration system to remove light waste (e.g. straw and husks) and dust. The farmer carries out the sorting themselves on their farm, and owning a sorter provides them with unrestricted access to the equipment whenever needed. For example, grains can be sorted continuously throughout the year, according to market outlets.

- **Sorting system 6: Semi-mobile CUMA-based sorter for carrying out final cleaning, with a manager responsible for the sorting processes**

This sorting system is used by one farmer. This system comprises a single optical sorter, which sorts grains according to colour using a camera and ejection system. It is shared under the CUMA status. This sorting system makes it possible to remove impurities that differ in colour from the main crops (e.g. stained grains and weed seeds of similar size and density). This piece of agricultural equipment is semi-mobile, meaning that two fixed locations have been designated, with a person appointed as the sorting manager at each location. The sorting fee charged by the CUMA covers the use of the equipment and is calculated on the basis of a committed volume and the duration of use.

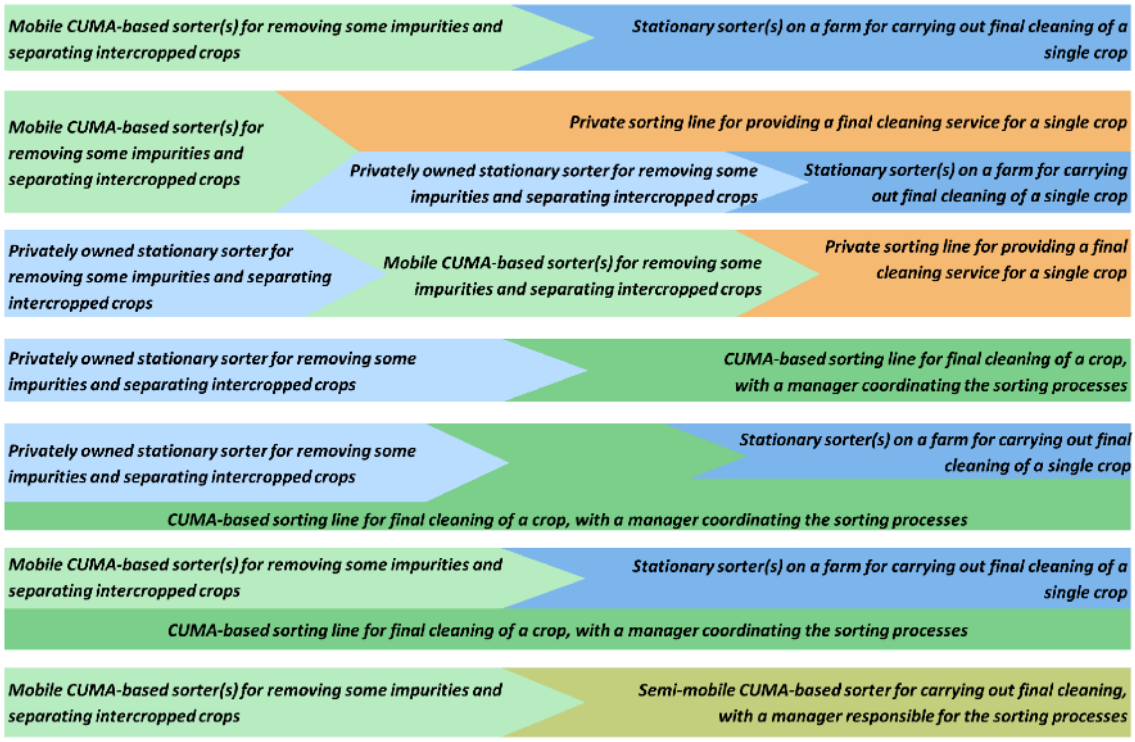


Figure 6: Arrangements of the six sorting systems identified among the surveyed farmers. Each colour represents one sorting system and each line refers to one case study.

As illustrated in Figure 6, the surveyed farmers use several sorting systems, which they combine and arrange differently according to the functions of each system, in order to achieve a grain quality that meets their expectations for different market outlets.

3.3.2 Different logics for using sorting systems to grow intercropped species for human consumption

- **Ideal type 1: The sorting system as the cornerstone of the production and valorisation of a crop with high social or heritage value**

This first ideal type concerns five farmers (out of 9). They grow a small number of intercrops, most of which they sell through long supply chains. For one particular crop, they choose to control all stages of production, from the field to valorisation. The sorting system plays a central role in their practices, as final cleaning enables them to sell through short supply chains, or even directly to consumers, a product that is ready for consumption (flour or lentils in the cases studied). In all cases, this crop is selected for its social value (human contact through short supply chains) and/or heritage value (a crop associated with the cultural heritage of a particular region). The species grown by these farmers are cereal–legume or oilseed–legume intercrops (lentil–rye, lentil–camelina, or wheat–faba bean). From an agronomic perspective, for these farmers, intercropping provides a supporting effect (lentil–rye and lentil–camelina), increases the protein content of cereals, and provides soil cover to control weeds (lentil–camelina), while also helping to secure yields in unfavourable years. The species are sown using different types of equipment (e.g. disc drill or a combined seed drill-tine harrow), but always in the same row and at the same depth.

Two farmers practice mechanical weeding, making at least one pass with a hoeing machine or tine harrow in winter or spring. This operation helps limit weed presence, thereby facilitating harvesting and sorting. Other farmers cannot access their fields because they are too wet at this time of year and therefore omit this operation. Harvesting is carried out either with a conventional combine harvester equipped with straw walkers, with a combine harvester fitted with a flexible cutterbar (to harvest grains close to the ground while avoiding bringing stones into the grain tank), or in a two-stage process, first mowing and windrowing and then harvesting with a pickup header replacing the cutterbar (to facilitate threshing, limit bruchid damage, and allow the grains to reach maturity).

The grains are sorted relatively soon after harvest to avoid the risk of heating caused by the possible presence of green material or moisture in the harvested grains. An initial pass through a screen grader (mobile rotary or stationary flat-screen) is used to clean and separate the crops. The subsequent stages vary considerably between farmers, who use different sorting systems to achieve the desired quality. Only the crop intended for short supply chains for human consumption continues through the sorting process until it is 'fit for human consumption'. It is sold as whole grain (lentil) or processed into flour (wheat), for example for supermarkets, farmers' shops, institutional kitchens, or artisanal food processors. This food-grade quality is achieved through a final cleaning system that includes an optical sorter, sometimes operated through a CUMA or by a private service provider. The other intercropped crop is either sold through long supply chains or used on the farm as animal feed or seed. Sorting residues are always valorised, either by livestock farmers as animal feed, as seed, or through anaerobic digestion.

- **Ideal type 2: Sorting systems as a means of growing and processing intercropped grains**

This second ideal type brings together three farmers. They all grow a large number of intercrops, most of which are sold through short supply chains, either as grain or after processing (milling, oil pressing). They place strong importance on controlling all stages of production, from the field to valorisation of the harvested products. Sorting systems are essential to their operations because they enable them to achieve food-grade quality and to sell directly or through short supply chains products that are ready for consumption (bread, flour, or lentils in the cases studied). In addition, all the farmers interviewed expressed a desire to regain greater control over the marketing of their products by prioritising short supply chains. In all cases, these crops are selected for the diversification they bring to both the crop succession and the range of products sold. The agronomic benefits of intercropping are also important, as is the ability to valorise the resulting products. Intercropping provides a supporting effect (barley–lentil), increases nitrogen fixation and its availability to the cereal, and provides soil cover to control weeds, while also helping to secure yields when one of the two crops performs poorly (e.g. barley–red lentil).

The intercrops examined in this study are cereal–legume intercrops (oat–lentil, wheat–faba bean, and barley–lentil). All farmers use farm-saved seed and varietal mixtures for cereals. According to them, reusing grain from one year to the next increases crop resilience. The intercrops are sown using different types of equipment: disc seed drills; disc seed drills combined with tine harrows; or disc seed drills with rotary harrows and a double hopper. In all cases, the crops are sown in the same row and at the same depth. Priority is given to the crop that is processed or sold directly and generates the highest added value. Some farmers carry out mechanical weeding, making one or two passes with a hoeing machine or tine harrow in spring. This operation reduces weed presence, thereby facilitating harvesting and sorting. Harvesting takes place between mid-July and early August. Farmers either use CUMA harvesting equipment and a driver, adjusting the machine settings to facilitate subsequent sorting; carry out a two-stage harvest (mowing and windrowing the crop before harvesting it with a pickup header); or combine these two techniques depending on field conditions.

One farmer stores the grain, ensuring that it is sufficiently dry, and carries out sorting in autumn, when they have more time, whereas the others sort the grain immediately after harvest. Several passes through one or more screen graders (rotary or flat-screen, mobile or stationary) both clean the crops by removing impurities of different sizes through the screening system (e.g. fine grain, broken grains, thistles) and light impurities through aspiration (e.g. dust, wild oats, black-grass), while also separating the intercropped species.

Only the crop intended for human consumption through short supply chains continues through the sorting process until it is fit for human consumption. It is sold as grain (lentil) or processed into flour (wheat), either directly (bread sold at markets, pasta and lentil sold through a farm shop) or through short supply chains to supermarkets, institutional kitchens, or restaurants, for example. This food-grade quality is achieved through a final cleaning system that includes an optical sorter,

sometimes operated through a CUMA or by a private service provider. The other intercropped grains are either sold through long supply chains or used on the farm as animal feed or seed. Sorting residues are always valorised: by livestock farmers as animal feed, through composting, or through anaerobic digestion.

- **Ideal type 3: Achieving a good price through the sorting system**

This third ideal type concerns only one farmer. He grows a small number of intercrops, which he sells through long supply chains, as is the case for crops grown as sole crops. The sorting system plays a central role in his farming practices because it enables him to separate the species and remove most impurities to be accepted by the cooperative without penalties. Indeed, harvests containing high levels of impurities are paid at a lower price by the cooperative. By reducing the impurity level to 'less than 3%, by sorting it, actually, that's the baseline, so there's no penalty, and it allows me to [...] it gives me sorting residues, and it allows me to feed my animals,' he maximises the selling price of the two main crops sold through long supply chains while also valorising the sorting residues (which would otherwise not be paid for) as feed for his sheep flock. The choice of intercrops is determined by their market outlets and by the size of the seeds of each species, in order to facilitate sorting.

The intercrop sown and studied is lentil–camelina, which is of interest because of camelina supporting effect. It also offers an economic advantage, as both crops have high added value, making sorting a necessary condition for maximising their selling price. The intercrop is sown with a disc seed drill (both crops are sown in the same row and at the same depth). Priority is given to lentils, which are the higher-value crop. The farmer does not carry out mechanical weeding. Instead, he relies on the position of the intercrop within the crop rotation (preferably early in the rotation) to benefit from low weed pressure in the field. For harvesting, he uses a two-stage process, mowing and windrowing the crop before harvesting it with a pickup header mounted on the combine harvester front, replacing the cutter bar. The advantage of this technique is that it brings 'all the grains to the same stage of maturity.'

Nevertheless, he sorts the grain soon after harvest because he considers that camelina is a 'sensitive crop'. An initial pass through a rotary screen grader separates the two crops and removes impurities of different sizes. The camelina is then passed through the same grader a second time before being sent to the cooperative. The lentils are passed through an indented-cylinder separator to remove grains of different shapes (long grains) before being sold to the cooperative. He keeps a small proportion for seed production and for direct sales through word of mouth. He sorts this portion using a gravity chute, which provides greater precision when removing impurities of different shapes from small batches of grain.

The initial sorting stages are carried out using the system of "Mobile CUMA-based sorter(s) for removing some impurities and separating intercropped grains", while the final sorting stages for the lentils are carried out using the system "Stationary sorter(s) on a farm for carrying out final cleaning of a single crop".

4. COLLECTIVE ARRANGEMENTS TO USE, ADAPT AND (RE)DESIGN EQUIPEMENT FOR INTERCROPPING : A CROSS-ANALYSIS

Three lessons emerge from these studies. First, **collective arrangements are most frequent for sorting**, the most capital- and skill-intensive operation, **and for sowing**, where the adaptation of equipment relies often on mutual aid and shared ownership. Second, **harvesting is mainly carried out with farm-owned equipment or outsourced to contractors**, and is rarely organised through farmer-based collectives. Third, **collective organisations provide not only access to equipment but also skills through the sorting expertise of a CUMA employee**, or the mechanical skills of a fellow farmer.

Collective arrangements also involve difficulties, which should be considered when supporting it. For instance, with mobile CUMA sorters, setting up the equipment is time-consuming and requires space, and some members of the CUMA become discouraged when they have to sort their batches themselves. CUMA sorting lines with an employee depend on a single operator who concentrates the skills, and require the delivery and storage of batches to be coordinated. Other example, the farmers who rely most on collective resources (Logic 3 in Section 3.1; frugal design in Section 3.2) are also those whose practices depend most on the local availability of contractors, CUMA and sorting facilities.

Building on these learnings, our results point out **several conditions under which collective arrangements can support the development of intercropping**:

- **Support collective investment in sorting equipment.** Sorting equipment, especially optical sorters, has a high cost and is used only a few weeks a year, which makes individual investment difficult. Support for collective sorting lines and mobile sorters can make intercrops accessible to more farmers.
- **Fund skills, not only equipment.** Sorting skills are mainly acquired through experience. Supporting the employment or training of shared sorting employees, and the pooling of know-how on settings and sorting appears as important as funding the equipment itself.
- **Support equipment adaptation, self-building and sharing.** Farmers develop intercropping by modifying, combining and repurposing equipment, buying second-hand or sharing it. Support should also cover these pathways and not only the purchase of new equipment in order to value farmer-designed solutions. Note that the CUMA model is specific to France, but equivalent forms of equipment sharing exist in other EU countries (e.g. machinery rings in UK or cooperatives). Using the typologies presented in this deliverable could be useful to diagnose which forms of collective organisation exist in the different countries, and which are missing, for sowing, harvesting and sorting intercrops.

- **Organise local sorting and marketing chains.** Connecting farmers, contractors, sorting facilities and processors at territorial level could help to align sorting capacity with outlets for human consumption.
- **Mobilising EU instruments.** At EU level, these levers can build on existing instruments of the Common Agricultural Policy in order to: (i) finance collective sorting equipment and the adaptation of existing machinery, (ii) support the setting-up of collective organisations and (iii) improve knowledge exchange and information actions in relation with farm advisory services that can support the training of sorting employees and the dissemination of farmer-designed equipment solutions.

5. GENERAL LESSONS & PERSPECTIVES

Several general insights emerge from this work and open up avenues for further research[7]:

- **Documenting the uses of agricultural equipment to engage with actors involved in the transformation of the sector**

The results of our work contribute, in different ways, to documenting the use of agricultural equipment in real-world situations. Documenting these uses helps make visible and recognise the work involved in farmers' appropriation and (re)design of agricultural equipment, while also shedding light on the conditions under which these processes are possible, in different work situations (e.g. the presence of CUMA, local investment support) and among different populations (e.g. differences in skills, know-how, physical abilities, or economic capacities).

To account for these uses, agronomic concepts and methods can provide useful analytical tools for characterising, in different ways, the interactions between agricultural equipment, the dynamics of cultivated ecosystems, and farmers' rationales in contrasting work situations. Whereas most studies conducted on this topic examine agricultural equipment one machine at a time (e.g. Ditzler and Driessen, 2022; Kefi et al., 2022), systemic approaches encourage researchers to consider 'agricultural machinery fleets' in order to take into account how actions are arranged throughout crop cycles (Fouillet et al., 2026; Pham, 2024). Systemic approaches to cultivated environments can also shed light on interactions between pieces of equipment, depending on their characteristics and modes of use, and the dynamics of the biotic and abiotic components of agroecosystems. Research on the study of farming practices (e.g. Landais et al., 1988) also provides useful analytical tools for accounting for the situated reasoning of workers when using equipment adapted to what they want and are able to do in their specific situations. Looking ahead, we believe it would be particularly valuable to collectively build on methodological developments for characterising these uses, depending on how we intend the resulting knowledge and materials to be used.

[7] These general findings were published in a French-language article by Salembier et al. (2026)

Documentation is not an end in itself, and it appears important to consider how it should be conducted in relation to the potential uses of the resulting materials. Our experiences and the activities carried out within the CUMA network show that these materials can be used to engage with equipment designers about the 'situations of use' of their equipment (Cerf et al., 2024), as well as with actors who finance its acquisition or adaptation. They can also provide reference points for facilitators, advisors, and extension workers supporting intercropping. They can further be shared as a 'source of inspiration' for those involved in diversification processes on their farms.

Several issues nevertheless remain important when documenting these uses. These include **the need to coordinate research on the topic**, to ensure that participants benefit, directly or indirectly, from the documentation produced, and to be clear with them about how the resulting findings will be used, so as to enable their informed participation in the research.

- **Supporting the on-farm design and appropriation of equipment to implement intercropping**

The results of our studies show that the evolution of agricultural equipment for intercropping does not only involve the acquisition of new machinery. It also involves technical adjustments, design, as well as the sale and abandonment of equipment. Pham (2024) shows that farmers simultaneously undertake a range of changes over time and across different pieces of equipment, and that the way they approach these changes depends on the 'stages,' questions, and events that shape their trajectories. In practice, adapting agricultural equipment and its uses is a form of work 'in its own right,' involving learning processes and dedicated resources.

Moreover, a small but growing body of studies and reports highlights the unsuitability of certain types of equipment for particular groups of users and for specific work situations (e.g. women, people with disabilities, and people facing economic difficulties – Bairwa et al., 2022; Nascimento et al., 2026; FNCUMA, 2025). These findings raise questions about existing support mechanisms. Beyond the learnings proposed in Section 4 (support for equipment adaptation, self-construction, sharing and collective ownership, and not only for acquisition), **further research is needed to design forms of support adapted to different groups of users**.

Designing and supporting the appropriation of 'agricultural equipment in motion' - equipment capable of adapting as farming practices evolve and suited to different populations of users - therefore represents a major challenge. The sociotechnical conditions underpinning such appropriation / (re)design in different territories would benefit from further investigation, building for instance on the work of Thareau et al. (2025), Angeli-Aguiton et al. (2025), and Brunier and Pinaud (2022).

- **Collective dynamics among farmers driving the appropriation and design of equipment**

As already demonstrated extensively by Lucas et al. (2019) and Cornée et al. (2025), our findings show that local arrangements can, under certain circumstances and conditions, support the appropriation, acquisition, use and (re)design of equipment. In particular, Bodey (2026) shows that grain sorting within a CUMA offers four main advantages, which are consistent with previous research on the topic (Lucas and Gasselin, 2016, 2018, 2019; Yan et al., 2026):

1. It gives farmers access to high-performance equipment with a high upfront purchase cost by facilitating equipment sharing and regular renewal, despite the fact that such equipment is specialised and not used on a daily basis.
2. It helps reduce mechanisation costs by charging for equipment based on actual use. For example, one farmer highlighted the advantage of having 'equipment for nothing throughout the year and only paying in January or February of the following year. Isn't that a good deal?', as well as the possibility of arranging the billing date and sharing the often substantial costs of equipment repairs and maintenance, since 'the CUMA advances all the costs.'
3. Seed sorting within a CUMA can also encourage some members to use agricultural equipment that they would not have invested in individually. The availability of sorting equipment and exchanges between peers can contribute to changes in farming practices.
4. Finally, access to skilled labour and the pooling of expertise through a CUMA employee or a mutual-aid scheme can facilitate the implementation of practices for which farmers lack either the necessary skills or the willingness to devote time. Indeed, in CUMA where each member has to carry out the sorting themselves, some farmers may become discouraged. In other cases, however, concentrating sorting expertise within the CUMA can greatly facilitate the sorting process from the farmers' perspective.

These advantages should be read together with the difficulties of collective sorting discussed in Section 4 (e.g. time needed to set up mobile sorters, dependence on a single operator, coordination of batch delivery and storage). The findings of Pham (2024) also corroborate, from a longitudinal perspective, the role of local arrangement dynamics in processes of equipment appropriation and design. These dynamics may take the form of contracted services, equipment loans between farmers, joint acquisition, buying or selling, support with equipment use, or repair.

- **Enriching the agronomic perspective on intercropping through the lens of agricultural equipment**

Agronomy has paid very little attention to agricultural equipment, and in most research and development organisations, 'agronomy' and 'agricultural equipment' are addressed separately and in a disconnected manner (Bellon Maurel and Huyghe, 2017; Salembier et al., 2020; Bakker et al., 2026). Yet, as recent studies have shown, integrating equipment into agronomic reasoning can enrich the ways in which agroecosystems are approached and help identify certain challenges that need to be addressed to support transitions.

At the field scale, examining equipment use invites us to consider other dimensions of agroecosystems, or to characterise existing dimensions differently. For instance, Fouillet et al. (2026) show that sowing depth and sowing pattern are two key properties of species mixtures, which both influence and are influenced by equipment characteristics and directly interact with species selection and development. **Yet these two characteristics (sowing depth and sowing pattern) are not taken into account in research on the topic** (e.g. Verret et al., 2020; Gardarin et al., 2022). Fouillet et al. (2026) also highlight the importance of considering the seed size of the intercropped species in order to ensure consistency between the choice of sowing, harvesting, and sorting equipment.

At the farm and territorial scales, examining equipment invites us to broaden our perspective on the sociotechnical conditions underlying changes in farming practices. Various authors have shown that supporting diversification requires consideration of potential market outlets, input suppliers, and opportunities for local agronomic advice (e.g. Revoyron et al., 2022). Considering equipment in relation to intercropping further broadens this perspective by drawing attention to local dealer networks, financial support schemes for equipment purchases, equipment repair and advisory networks, and taxation. **As agronomists, we therefore need to consider other dimensions of 'action situations' that enable practices to be tested, abandoned, and renewed, recognising that equipment enriches our perspective on practices and condition their evolution.**

Enriching the agronomic perspective on intercropping through the lens of equipment also appears to be a major challenge for agronomy education and training. At present, too few educational programmes combine an 'agronomic approach' with an 'agricultural equipment engineering approach,' as reflected in curricula ranging from vocational secondary education to higher education in agricultural studies. Our experience shows that documentation of agricultural equipment uses and trajectories of changing practices can, for instance, provide valuable resources, among others, for raising awareness among students and professionals of the challenges involved in appropriating and redesigning equipment according to specific work situations.

6. CONCLUSION

This deliverable explores how farmers use and design agricultural equipment to implement intercropping, and how collective arrangements support these processes, drawing on three complementary studies conducted in France.

- **Logics of equipment use.** Farmers do not follow a single path, indeed some minimise mechanisation costs by using the equipment already present on the farm, others adapt their equipment to the characteristics of the species, and others choose their intercrops according to the equipment available locally, through contractors, CUMA and shared sorting facilities. Sowing depth, spatial arrangement and seed size emerged as key properties linking the design of intercrops with the choice of adapted equipment.
- **Design of equipment fleets over time.** Farmers' trajectories combine the repurposing, modification, self-building, purchase, sharing and abandonment of equipment. The three design logics identified (frugal, standardised and flexible) show that collective organisations are central when investment capacity is limited, and complementary when farmers expect greater autonomy.
- **Sorting systems.** Six sorting systems were identified, ranging from privately owned to CUMA-based sorting lines operated by a dedicated employee. Farmers combine these systems to reach the quality required by their outlets, and sorting becomes the cornerstone of intercrops particularly when valorised for human consumption through short supply chains.
- **Role of collective organisations.** Across the three studies, collective organisations boost intercropping practices, especially for sorting, the most capital- and skill-intensive operation, and for sowing. Indeed, they provide access not only to equipment but also to skills and shared know-how, while raising coordination challenges. **Supporting intercropping in the EU therefore requires helping collective investment, shared skills and equipment adaptation, but also connecting sorting capacity with local outlets**. Extending these analyses to other EU contexts, where forms of equipment sharing differ from the French CUMA model, is an important perspective for future work.

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INTERCROP VALUES

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