Agroecology Initiative

Technical Report

Synthetic report on the co-design and experimentation of agroecological technologies with dairy farmers of the Agroecological Living Landscape of Burkina Faso

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Contents

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Abstract (long)

In Burkina Faso, the implementation of an agroecological dairy farming system is a strategic necessity if we are to meet the new expectations of the downstream dairy value chain, i.e. tasty, diversified dairy products made from local milk rather than milk powder, produced under conditions that meet sustainability criteria, and meeting the needs of processors for quality milk available in sufficient quantities all year round. This is why, as part of the Agroecology Initiative (AEI), we have been working with dairy farmers on the co-design and experiment of agroecological technologies based on: Biodiversification of the forage system, strengthening crop-livestock interactions and recycling co-products as key agroecological principles to intensify and sustainably develop local milk production in Burkina Faso. The approach consisted in setting up an On-farm Experimental Design for Agroecology (OnEDA) comprising a package of agroecological technologies consisting of: (i) forage and seed production plots, called Fodder Demo-Plot (FDP); (ii) farm co-product management advice using the *CoProdScope* tool ; (iii) dairy production units in which cows receive balanced, economical diets developed using the *Jabnde* tool, and (iv) a system for recovering animal waste to produce manure in covered manure pits that are efficient for covering the manure needs of crops. In reality, this is a systemic experimental scheme for the integration of crops and livestock (forage system - dairy production unit). In 2023/24, some 60 dairy farmers affiliated to the Bobo-Dioulasso Dairy Innovation Platform have volunteered to host the experiment. The Fodders Demo-Plots produced a median value of 2,500 and 1,500 kg/ha of biomass for cereals and legumes respectively. The seeds produced enabled the Fodders Demo-Plots to be re-established in year N+1 on the farms of over 100 farmers. The use of *CoProdScope* led to an increase in the contribution of crop co-products to the farm's fodder requirements, rising from 8.5% to 26% between year N and year N+1. The use of *Jabnde* enabled establishing balanced diet for 48 lactating cows using forage from the Fodders Demo-Plots. Covered manure pits produced high-quality manure to improve soil fertility. The participatory agronomic evaluation of the technologies tested by farmers in the forage system and dairy production units showed that farmers were very positive about the package options that incorporated the most agroecological elements (pulses and manure for the forage system, intensive use of quality forage to feed the cows). In terms of production, the OnEDA approach partially achieved the objectives of the DIP and the ALL, namely to increase the quantity and regularity of local milk production, and to strengthen dairy farmers' technical skills in agroecological techniques. Overall, the implementation of the agroecological package among dairy farmers has helped to strengthen the resilience of the milk production system in the Bobo-Dioulasso dairy basin. Dairy farmers still need to improve: the management of Fodder Demo-Plots by protecting plots from livestock intrusion and adopting good fodder storage and conservation practices; the use and management of co-products; feeding dairy cows at an affordable cost and keeping abreast of weather alerts to know the best time to sow.

Keywords: dairy farming, agroecological innovation, forage production, cow rationing, co-product recycling

Abstract (short)

In Burkina Faso, the implementation of an agroecological dairy farming system is a strategic necessity to meet the new expectations of the downstream of the dairy value chain, i.e. tasty and diversified dairy products made from local milk rather than milk powder. This is why, as part of the Agroecology Initiative (AEI), we have been working with dairy farmers on the co-design and testing of agroecological technologies. The approach consisted in setting up an agroecological package comprising: (i) forage and seed production plots, called Fodder Demo-Plot (FDP); (ii) farm co-product management advice using the *CoProdScope* tool; (iii) dairy poduction units using the *Jabnde* tool and (iv) a manure recovery system to produce manure in efficient covered manure pits. In 2023/24, some 60 dairy farmers affiliated to the Bobo-Dioulasso Dairy Innovation Platform volunteered to host the experiment. The FDPs produced a median value of 2,500 and 1,500 kg/ha of biomass for cereals and legumes respectively. The seeds produced enabled Fodders Demo-Plots to be re-established in year N+1 with over 100 farmers. The use of *CoProdScope* led to an increase in the contribution of crop co-products to the farm's fodder requirements, rising from 8.5 to 26% between year N and year N+1. The use of *Jabnde* made it possible to establish balanced diets for 48 lactating cows using forage from the Fodders Demo-Plots. Covered manure pits produced high-quality manure to improve soil fertility. Overall, the implementation of the agroecological package among dairy farmers has strengthened the resilience of the dairy production system in the Bobo-Dioulasso dairy basin. Farmers still need to improve: management of Fodder Demo-Plots; use and management of co-products; feeding dairy cows at an affordable cost and keeping abreast of weather alerts to know the best time to sow.

Keywords: dairy farming, agroecological innovation, forage production, cow rationing, co-product recycling

1. Introduction

Increasing demand for dairy products in West Africa, and recent changes in the price of imported milk powder, represent an opportunity to intensify and develop local dairy production, collection and processing (Sib et al., 2018 ; Duteutre and Vidal 2018 ; Vall et al., 2021). In Burkina Faso, as elsewhere in West Africa, dairy production is largely ensured by extensive pastoral and agropastoral systems, and to a lesser extent by semi-intensive and intensive farming systems (Vall et al., 2021). The local milk industry is hampered by the low productivity of cows, the seasonal nature of production, which makes collection difficult, and the relatively low capacity of processing units. To cope with the seasonal nature of production, largely due to the food deficit in the dry season, farmers are diversifying their strategies for supplementing their cows during this period with: increased storage of crop residues, the use of agro-industrial co-products and expensive feed concentrates beyond the reach of most farmers. In addition to these resources, interest in forage production on farms is beginning to grow. For a long time, forage crops were promoted by research and development, but adopted very little, as they were less suited to farmers' needs while there was still room for natural grazing to feed the animals (Landais and Lhoste, 1990 ; Vall et al., 2017). What's more, research into forage crops was confined to research stations, with very little application in the real environment where adoption takes place. Today, the situation is changing. The landscape is being recomposed, pastures are less and less accessible, land pressure is increasing, the original poverty of Burkina Faso's soils is aggravated by agricultural practices unfavourable to their sustainability, climatic uncertainties are growing, with an increase in the frequency of extreme events, and transhumance is increasingly hampered. As a result, livestock farmers are looking for ways to adapt and sustainably increase their self-sufficiency in forage and manure, but need technical and organizational support to do so.

Agroecological approaches are gaining in importance as a response to the challenges of sustainably increasing agricultural production and ensuring resilience in the face of multiple changes. They present ways of transforming agricultural and food systems through a number of principles whose implementation in the local dairy value chain could be highly beneficial. These include seven of the thirteen principles proposed by de Wezel et al (2020) : (i) recycling (preferably using local renewable resources and closing nutrient and biomass resource cycles as much as possible); (ii) input reduction (reducing or eliminating dependence on purchased inputs and increasing self-sufficiency); (iii) soil health (ensuring and improving soil health and functioning for better crop growth, notably by managing organic matter and enhancing soil biological activity) ; (iv) biodiversity (maintaining and enhancing species diversity, functional diversity and genetic resources); (v) synergy (strengthening positive ecological interaction, synergy, integration and complementarity); (vi) knowledge co-creation (strengthening the co-creation and horizontal sharing of knowledge, including local and scientific innovation, in particular through farmer-to-farmer exchange. Local and scientific innovation, in particular through farmer-to-farmer exchange) and (vii) social values and diets (building food systems based on the culture, identity, tradition, social and gender equity of local communities, which provide healthy, diversified, seasonal and culturally appropriate diets, healthy, diversified, seasonal and culturally appropriate diets).

Based on these agroecological principles, diversifying the production of high-nutritional-value forages, producing high-quality manure, making efficient use of crops and livestock co-products for forage and manure, reasoned management of dairy cow diets on dairy farms appear to be agroecological options that meet farmers' expectations for increasing milk production at lower financial cost, as forages are both an alternative to traditional dry-season food resources (cereal straw, spontaneous pastures with low food value in the dry season, agro-industrial co-products). Better recycling of livestock and crop co-products to produce manure will be a great help to forage production in dairy farms. And finally, efficient management of co-products and diets will help reduce input bills, while improving soil and livestock maintenance on the farm.

How can we support this dynamic while learning the lessons of the past? Farmers very often need certainty in situ before adopting an innovative technology proposed by research and development. Their rationality, expectations and constraints must therefore be considered, by placing them at the heart of the design process, so that they can participate in steering the process to facilitate its appropriation. It is against this backdrop that the Agroecology Initiative (AEI) project is acting in Burkina Faso by setting up a On-farm Experimental Design for Agroecology (OnEDA), which aims to co-design, experiment and assess technologies based on agroecological principles, on-farm and with farmers.

This document synthesizes the results of co-design, experimentation and evaluation of agroecological technologies conducted with dairy farmer members of Burkina Faso's Living Landscape Agroecologique during the 2023-2024 experimentation campaign (Ouattara et al., 2024a ; Ouattara et al., 2024b). It describes the general approach to setting up the ONEDA, the results obtained and their involvement.

2. Processes and stages of co-design and experimentation

2.1. Setting up an Agroecological Living Landscape in Burkina Faso

In order to carry out its activities, the project team began by setting up an Agroecological Living Landscape (ALL-BF) based on the Bobo-Dioulasso Dairy Innovation Platform (DIP) (Sib et al., 2023a). The Bobo-Dioulasso DIP was set up during the Africa-Milk project in 2020. It grew out of the desire of local dairy value chain stakeholders in Bobo-Dioulasso to find a way of coming together to undertake actions to develop their respective activities. It is made up of dairy farmers, collectors affiliated to milk collection centers, private collectors, milk processing units, and public and private support services. DIP's initial target for 2020 was to collect 18,000 liters of milk a day to supply the city's processing units. In 2023, when the AEI was set up, and with the aim of facilitating the agroecological transition of the dairy value chain, the DIP was extended to include other actors, notably support services and external members, thus creating the ALL-BF (Figure 1).

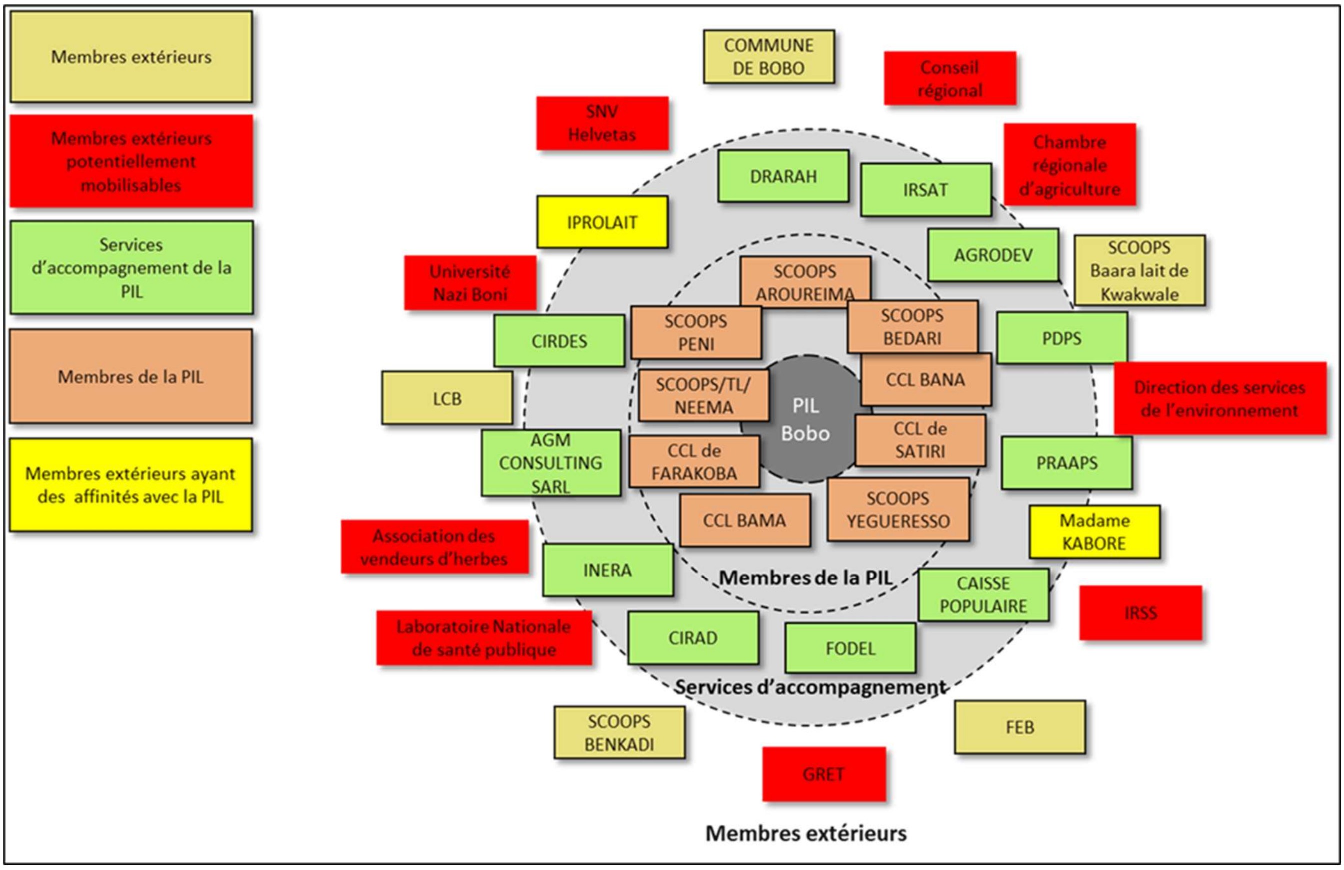

Figure 1. Dairy Innovation Platform expanded into an Agroecological Living Landscape

In its vision of the future of the dairy industry, the ALL-BF presents 3 objectives that specifically concern dairy farmers. These three objectives are as follows:

- Increase milk production and reduce milk production seasonality
- Strengthening farmers' technical skills
- Improving milk quality

Researchers and members of the ALL-BF board began by looking at how to operationalize these objectives in line with the principles of agroecology. This work led to the proposal to set up a On-farm Experimental Design for Agroecology (OnEDA) aimed at co-designing, experimenting and assessing a set of agroecological technologies with volunteer dairy farmers. This set of agroecological technologies has been named the agroecological package.

During a second workshop held in May 2023, focusing on the co-design of the agroecological package experiments, the On-farm Experimental Design for Agroecology (OnEDA) and the components of the agroecological package were presented to ALL-BF stakeholders. After being adjusted to take account of the recommendations, needs and constraints of the stakeholders, the OnEDA and the components of the agroecological package were validated by a plenary session. (Sib et al., 2023b). Today, the OnEDA is based on four (4) complementary components (Figure 2) :

1) The introduction of a forage and seed production system called Fodder Demo-Plot;
2) Smart management of crop and livestock co-products at farm level using the CoProdScope tool tool (Zoungrana et al., 2023);
3) The establishment of dairy production units with dairy cow diets based on Fodder Demo-Plots forages and designed using the *Jabnde* rationing tool;
4) The establishment of efficient covered manure pits to recycle livestock and crop co-products in good manure and use it for the farm crops and forage production;

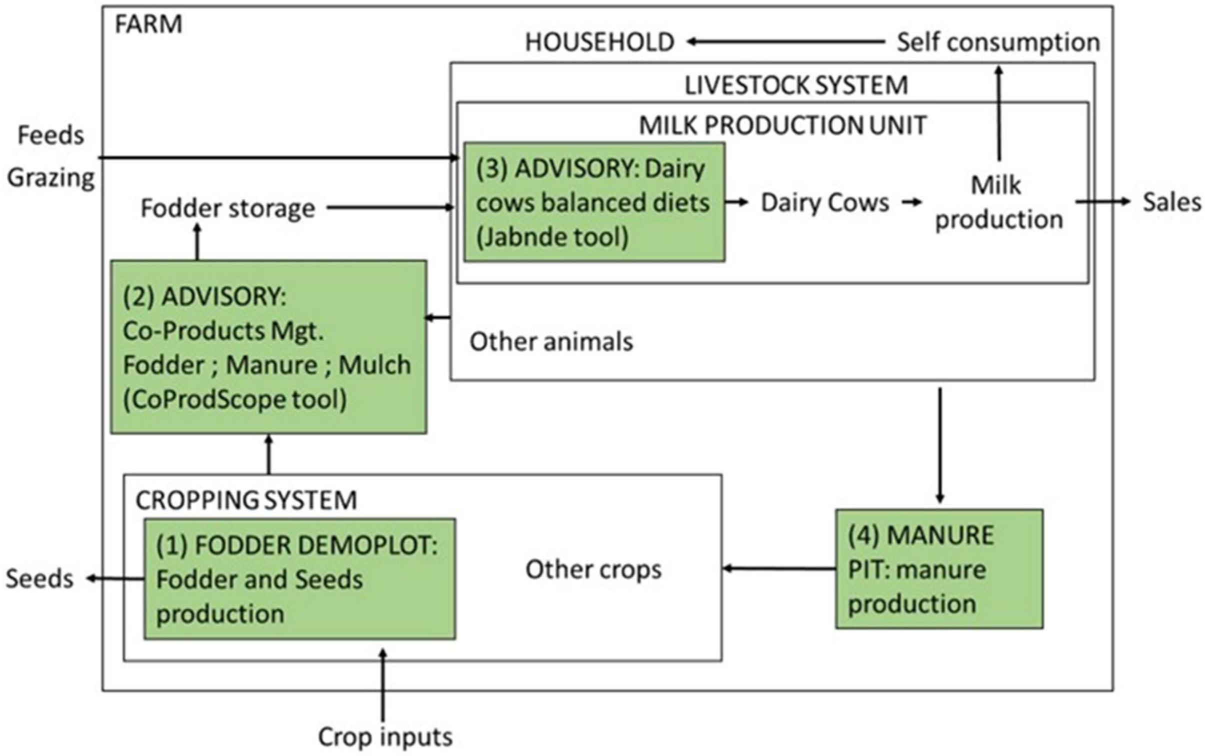

Figure 2. Presentation of the loop and cascade approach to co-design, experiment ans asses a more agroecological dairy farming system (OnEDA approach)

2.1.1. Setting up Fodders Demo-Plots

During the validation workshop for the OnEDA experimentations, 57 dairy farmers volunteered to set up Fodder Demo-Plots. These volunteers came from 9 Milk Collection Centers, i.e. an average of 6 volunteers per Milk Collection Center.

The principle of the Fodder Demo-Plot was to cultivate four crops for fodder and seed production on an area of at least 0.5 ha, at a rate of at least 0.125 ha for each Fodder Demo-Plot crop. The crops selected for the Fodder Demo-Plots were: (i) Maïs Espoir and Sorghum grinkan for cereals and (ii) Niébé Tiligré KVX 775-33-2G and *Mucuna pruriens var. deeringiana* for legumes (Figure 3). This choice was made in consultation with volunteer farmers. The quantities of seed made available to farmers were at least 3; 1.5; 2; and 4 kg respectively for maize, sorghum, cowpea and mucuna. For each crop, 2/3 of the cultivated area was dedicated to forage production and the remaining 1/3 to seed production. The seed produced was divided into three equal parts: one part was intended for replication of the Fodder Demo-Plot in year N+1 (2024) by the volunteer farmer (Mother), and the other two parts were given free of charge to volunteer neighbors (Babies) to implement the Fodder Demo-Plot on their farms in year N+1 (Figure 4). This principle of seed redistribution was chosen because, in theory, it would enable the practice of forage cultivation to spread rapidly (Theoretical evolution of the number of Fodder Demo-Plots: Nb FDP (n) = Nb volunteers year 1 x $3^{(n-1)}$; n being the year).

In addition, 15 volunteer farmers willing to take up forage production were identified in the immediate vicinity of the Milk Collection Centers. These farmers produced fodder which they sold or exchanged with dairy farmers to feed their cows.

A monitoring sheet has been designed for technical and socio-economic monitoring of forage crops. It records information on: the technical itinerary, biomass production and yield, seed yields, workload, income and expenditure. This follow-up was carried out in three passages. Two types of forage yield were determined. These were potential yield and harvested forage yield. Potential yield was determined using the yield square method, with four $4m^2$ yield squares used on each crop plot prior to grain harvesting. Harvested forage yield was determined by considering the quantity of forage actually harvested after grain harvest by the farmer.

Figure 3. Views of four forage crops in the Fodders Demo-Plots

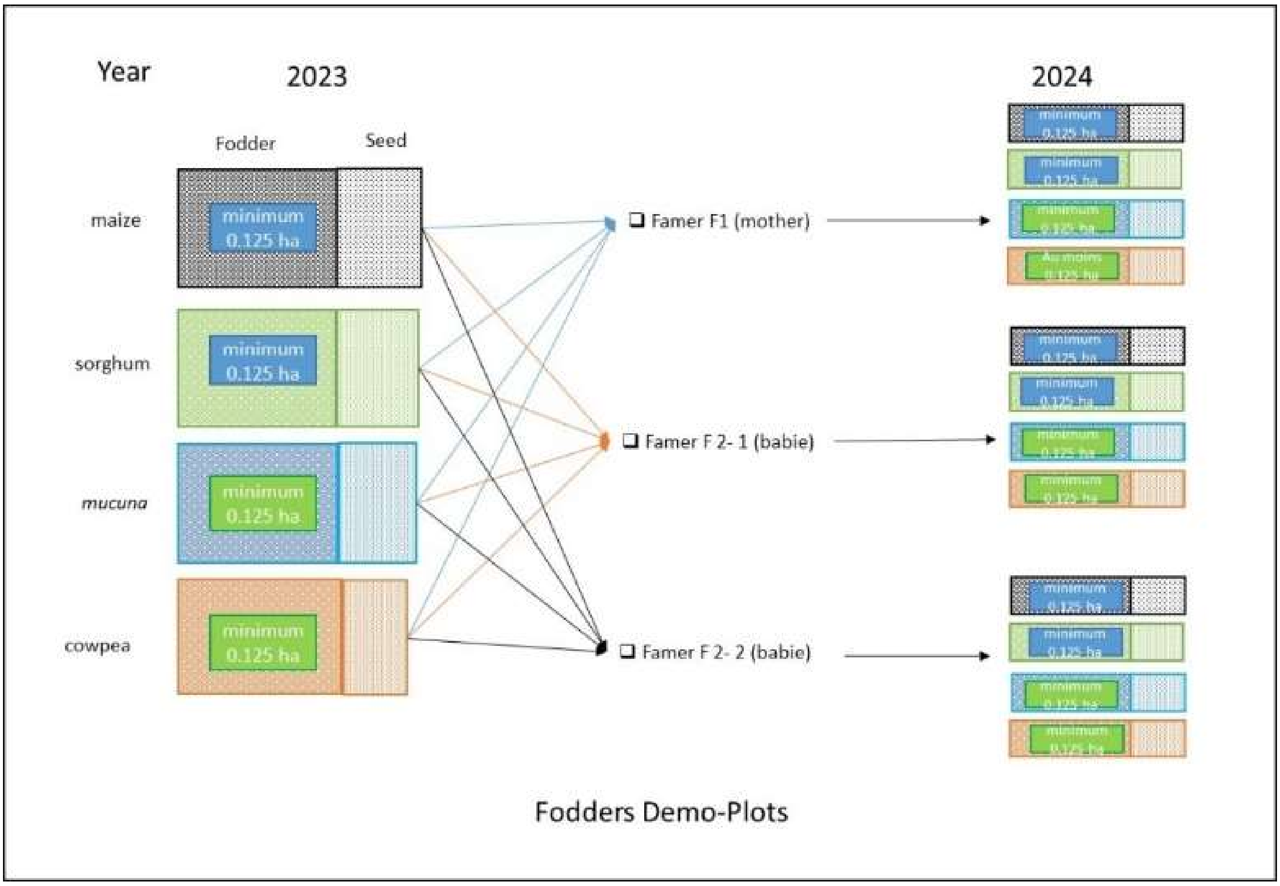

Figure 4. Principle of Fodders Demo-Plots experimentation

2.1.2. Integrated management of crop and livestock co-products on the farm using the *CoProdScope* tool

The *CoProdScope* tool was used to advise farmers on the optimal (smart) management of crop and livestock co-products as fodder and manure. In 2023/24, 10 volunteer farms were involved in using the *CoProdScope*. The *CoProdScope* currently runs on Microsoft Excel, and its use is based on interaction between an agricultural advisor and a farmer. The *CoProdScope* is a simple tool designed for agropastoralists in the savannah zones of West and Central Africa, enabling them to: i) draw up an annual balance sheet for the management of crop and livestock co-products at farm level for the past year (N), and ii) advise the farmer on the management of crop and livestock co-products for the coming year (N+1). The assessment of the use of crop and livestock co-products covered the period from June 2022 to May 2023 (year N), and the advice the period from June 2023 to May 2024 (year N+1). The steps involved in carrying out the assessment were as follows:

- Stage1: collection of general farm information such as farmer identity, labor force and equipment (sheet 3 of the *CoProdScope*)
- Step 2: Livestock inventory and estimate of livestock available livestock co-products (*CoProdScope* sheet F4.3)
- Step 3: Crop inventory and estimate of available crop co-products (sheet 4.2 of the *CoProdScope*)
- Step 4: Drawing up an annual balance sheet of the farm's forage, manure and mulch requirements.

Once the assessment of co-product use had been carried out, a strategy was devised in conjunction with the farm manager to generate advice for better use of crop and livestock co-products in year N+1 on sheet 5.2 (

Figure 5).

Figure 5. **Crop and livestock co-product management consulting sessions on two farms using CoProdScope**

2.1.3. Co-design of diets using the *Jabnde* tool and monitoring of dairy production units

Jabnde is a calculation and rationing tool developed by CIRAD in the consumer environment Microsoft Office - Excel and associated with macros and calculation routines programmed in Visual Basic for field use on a basic laptop computer (Lecomte, 2022). The tool has been developed to consider the characteristics of dairy farming in sub-Saharan Africa (local genetic types, grazing animals, local forage and feed resources). *Jabnde* can be used to produce individual diets for a herd of up to 29 head of cattle.

The experiment was carried out in the dairy production units of a sample of volunteer farmers who had properly implemented the Fodder Demo-Plot and had a large stock of forage. Out of an initial sample of 30 volunteer farmers, the experiment was successfully carried out with 20 volunteers. The ten other volunteer farmers had only stored cereal straw (of low feed value), which tends to lower the milk production potential of pasture-raised cows, or had no significant stock to conduct the experiment. On average, two cows per dairy unit were monitored during the course of the experiment, for a total of 48 cows.

Following the implementation of the Fodders Demo-Plots, the forage produced was stored for the rationing of dairy cows in the hot dry season (February, March and April 2024). In this way, *Jabnde* was used to establish balanced diets (i.e. diets that cover the cows' feed requirements in relation to the milk production target set by the farmer, considering the resources available on his farm, or in the local market) and at an economic cost acceptable to the farmer. The aim was to set up efficient dry-season diets, i.e. balanced and economically acceptable. The dairy production units were monitored in four stages:

- Step 1: Collecting reference and input data for *Jabnde*
- Stage 2: co-design of diets using *Jabnde* simulation
- Stage 3: Experimentation, adaptation and evaluation of selected diets

At the end of the co-design and experiment steps, an analysis of the perceptions of farmers who had tested the promising diets was carried out by means of individual surveys.

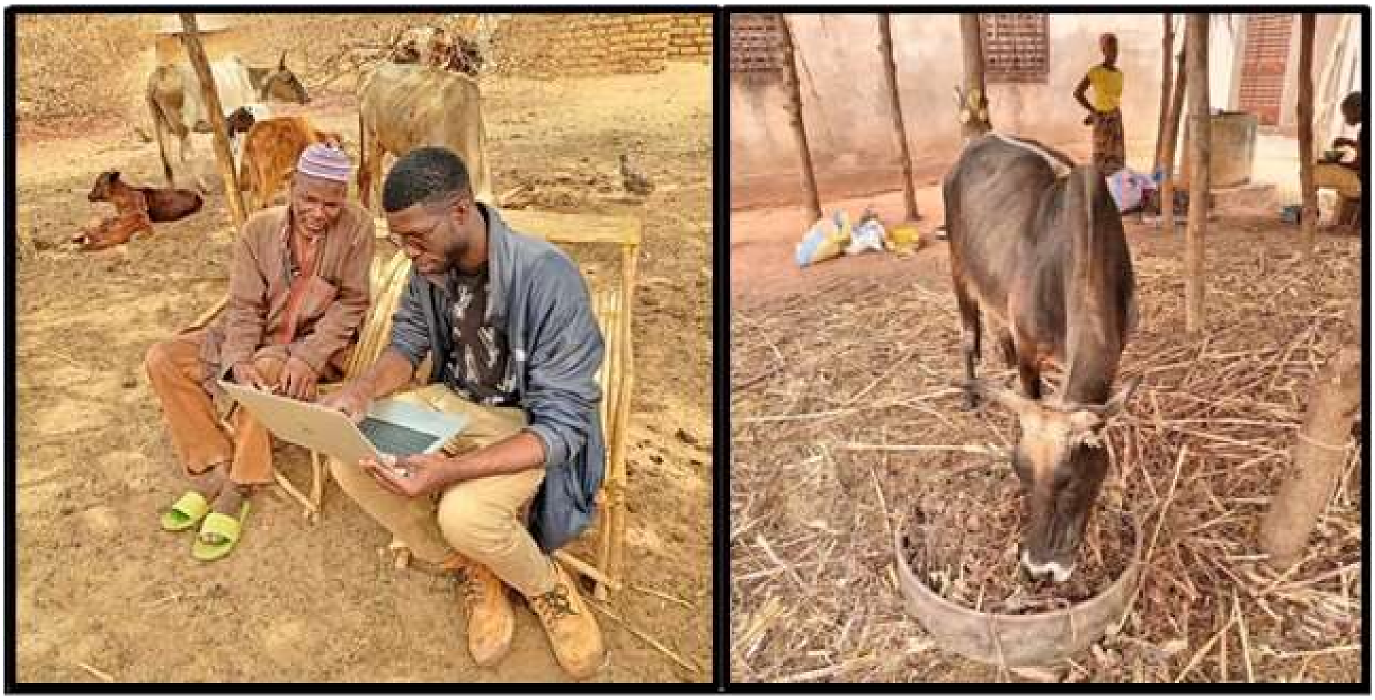

Figure 6. Ration co-design session in a dairy production unit

2.1.4. Setting up and monitoring efficient covered manure pits

Of the 57 farmers who volunteered to set up the Fodder Demo-Plot, 54 offered to install an Efficient Covered Manure Pit in 2023. These farmers were provided with cement for the construction of efficient covered manure pits. The planned pit volume was 10 m^3 with built-on kerbs. After filling, the pits were to be covered to accelerate decomposition and limit biomass losses. The constructed pits were supplied with livestock and crop co-products from the farm.

Before emptying the manure from the pit, samples were taken from five different locations on the two diagonals of the pit at depths of 0-30, 30-60 and 60-90 cm. An average sample was taken from each depth for laboratory analysis and weed seed stock assessment. The parameters to be measured were: (i) pH, Organic Matter (OM), Carbon (C), Nitrogen (N), Phosphorus (P) and Potassium (K) content and C/N ratio, and (ii) assessment of the density and diversity of weed species present.

For manure pit monitoring, a monitoring form has been designed to collect filling data. The information collected relates to: (i) pit construction (ii) pit filling and (iii) evaluation of manure quality and temperature measurements. Monitoring is monthly from the start of filling until the manure has matured.

2.1.5. Data collection and analysis

All data were collected using KoBoCollect. Statistical analyses were performed with R software, version 4.3.3 (R Core Team, 2024). Analysis of variance (ANOVA), Kruskal-Wallis and Wilcoxon tests were used to compare means. The validity conditions of each test were checked before they were performed.

Table 1. **Agroecological technologies co-designed and tested in Burkina Faso**

Website	Experimental agroecological technology	The concrete problem it tackles	Cycles in which the technology was tested	Domain[1]	Underlying agroecological principle(s)[2]	Origin[3]
Bobo-Dioulasso	Dynamic forage and seed production	Dry season forage deficit and high forage seed prices	June to November 2023	Forage productio n	Biodiversity, Participation, Co-creation of knowledge and Reduction of inputs	Research technology tested by the project team
Bobo-Dioulasso	Co-product management tool (*CoProdScope)*	Poor management of farm co-products	Review: June to May 2023 (year N) Board: June 2023 to May 2024 (year N+1).	Recycling farm co-products	Recycling, reducing inputs	(Zoungrana et al. 2023)
Bobo-Dioulasso	Setting up dairy production units using the *Jabnde* tool	Lack of rationing skills among dairy farmers; Low cow productivity	December 2023 to April 2024	Animal feed; Milk productio n	Participation, knowledge co-creation and input reduction	(Lecomte, 2022)
Bobo-Dioulasso	Production of high-quality manure using covered manure pits	Soil poverty	December 2023 to June 2024	Soil fertility	Soil health	Research technology tested by the project team

Field[1] : (e.g. soil fertility, integrated pest management, water management, mechanization, biodiversity, "systemic", etc.). Underlying principle of agroecology: refers to one or more of the 13 principles. Origin[3] : this is a technology developed as part of previous R&D interventions, a farmer's innovation or technology, a researcher's technology or a technology newly codified during the codification process followed for the initiative.

Table 2. **Experimental protocols established following the co-design phase**

Tests	Short name of experiment	Test cycle(s)	Name of villages / sites where the trial was set up	Number of farmers who set up the trial	Number of treatments included for each farmer	Replications established for each farmer
Setting up Fodders Demo-Plots	Forage and seed production	June to November 2023	Dafinso, Yégueresso, Kouakoualé, Bobo-Dioulasso, Satiri, Belle-ville, Farakoba, Bama, Bana	65	1	1
Managing farm co-products *with the CoProdScope* tool	Assessment and advice on valorization of farm co-products	Review: June to May 2023 (year N) Board: June 2023 to May 2024 (year N+1).	Farakoba, Kouakoualé, Bobo-Dioulasso, Yégueresso, Dafinso	10	1	1
Setting up dairy production units using the *Jabnde* tool	Rationing dairy cows	December 2023 to April 2024	Farakoba, Kouakoualé, Bobo-Dioulasso, Yégueresso, Dafinso, Bana, Bama,	20	1	1
Installation of efficient covered manure pits	Production of quality manure	December 2023 to June 2024	Dafinso, Yégueresso, Kouakoualé, Bobo-Dioulasso, Satiri, Belle-ville, Farakoba, Bama, Bana	47	1	1

NB: For all trials, each farmer constituted a replication.

Table 3. Monitoring and evaluation of agroecological package experiments

Tests	Short name of experiment	Key agronomic variables monitored or collected	Key socio-economic variables monitored or collected	Number of days in the field or exchange visits carried out	Producers' contribution to monitoring this trial (yes entirely/partially/no)
Setting up Fodders Demo-Plots	Forage and seed production	Technical itinerary, biomass yield, grain yield	Workload and expenses	5	Yes, entirely
Managing farm co-products with *the CoProdScope* tool	Assessment and advice on valorization of farm co-products	Quantity of livestock and crop co-products produced and purchased	---	2	Yes, entirely
Setting up dairy production units using the *Jabnde* tool	Rationing dairy cows	Quantity of each diet ingredient distributed per day and daily milk production	Cost of milk production and sales	18	Yes, entirely
Installation of efficient covered manure pits	Production of quality manure	Quantity of livestock and crop co-products used for filling	Cost of setting up and running the pit and workload	7	Yes, entirely

Legend: --- = no key socio-economic variables tracked

3. Results

3.1. Setting up and monitoring the Fodders Demo-Plots implementation dynamic

During the 2023/2024 experimentation campaign, seventy-two (72) volunteer farmers (57 dairy farmers and 15 farmers) were identified for the implementation of Fodder Demo-Plots. By the end of the experiment, 65 farmers (54 dairy farmers and 11 farmers) had implemented at least one Fodder Demo-Plot crop, i.e. a 90.28% completion rate. The dynamics of Fodder Demo-Plot implementation are shown in Figure 7.

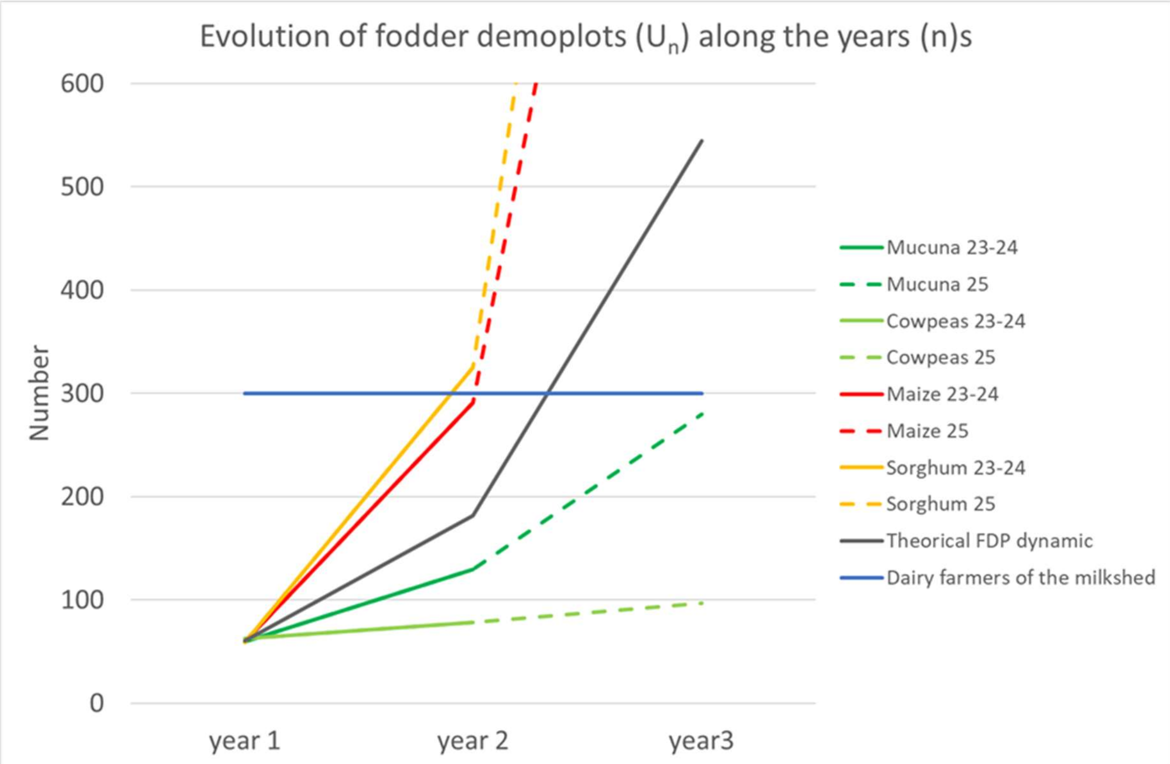

Figure 7. Evolution of the number of Fodders Demo-Plots: real for years 1 and 2 (2023, 2024), estimated for year 3 (2025)

3.1.1. Forage Demonstration Plot Areas

A Fodder Demo-Plot was installed at 54 volunteer dairy farmers during the 2023 crop year. For a planned area of 0.72 ± 0.49 ha/FDP, an area of 0.76 ± 0.73 ha/FDP was recorded, i.e. a surplus of 0.04 ha/FDP. The Milk Collection Center where volunteers set up the smallest area of FDP was Bama (0.38 ha/FDP), and the one where the largest average area of FDP was set up was Kouakoualé (2.66 ± 5.32 ha/FDP) (Table 4). In Kouakoualé, a cooperative of 7 volunteer farmers installed a large Fodder Demo-Plot of 4.85 ha, which explains the high FDP area in this collection center.

Table 4. Areas of dairy farmers' Fodder Demo-Plots aggregated by Milk Collection Center

Milk collection centers	Workforce	Planned areas (ha/FDP)	Total area planted (ha/FDP)	Average area planted (ha/FDP)	Difference between planted area and planned area (ha/FDP)
Bama	9	0.50 ± 00	3.44	0.38 ± 0.28	-0.12
Bana	6	0.50 ± 00	3.26	0.54 ± 0.16	0.04
Beautiful city	5	0.65 ± 0.22	2.19	0.44 ± 0.2	-0.21
Benkadi	6	0.81 ± 0.31	5.32	0.89 ± 0.69	0.08
Dafinso	4	0.50 ± 00	2.21	0.44 ± 0.09	-0.06
Farakoba	6	0.50 ± 00	3.42	0.57 ± 0.13	0.07
Kouakoualé*	8	1.99 ± 2.11	5.32	2.66 ± 5.32	0.67
Satiri	6	0.50 ± 00	2.63	0.44 ± 0.19	-0.06
Yégueresso	4	0.50 ± 00	1.91	0.48 ± 0.14	-0.02
Total	54	0.72 ± 0.49	29.70	0.76 ± 0.73	0.04

Legend: (*) = a cooperative of 7 volunteer farmers installed a large 4.85 ha Fodder Demo-Plot; ha/FDP = hectare per Fodder Demo-Plot.

Farmers identified to support dairy farmers with dry-season forage resources established an area of 0.99 ± 0.58 ha/FDP. This is greater than the planned area of 0.75 ± 0.22 ha/FDP, i.e. a surplus of 0.24 ha/FDP. The total area of farmers' FDPs was 10.57 ha (Table 5).

Table 5. Area of farmers' Demo-Plots aggregated by Milk Collection Centres

Milk collection centers	Workforce	Average area planned (ha/FDP)	Total area planted (ha/FDP)	Average area planted (ha/FDP)	Difference between planted area and planned area (ha/FDP)
Bama	2	0.75 ± 0.35	1.61	0.81 ± 0.33	0.06
Benkadi	1	1 ± 00	0.72	0.72 ± 00	-0.28
Dafinso	2	1 ± 00	3.71	1.85 ± 0.28	0.85
Farakoba	1	0.5 ± 00	0.85	0.85 ± 00	0.35
Kouakoualé	2	0.75 ± 0.35	2.96	1.48 ± 0.51	0.73
Yégueresso	3	0.5 ± 0.43	0.72	0.23 ± 0.08	-0.27
Total	11	0.75 ± 0.22	10.57	0.99 ± 0.58	0.24

Legend: ha/FDP = hectare per Fodder Demo-Plot.

If the overall recommendation was to implement the trial for each crop on at least 0.125 ha, the Figure 8 shows that this was not possible for many farmers, certainly due to land constraints on their farms. On the other hand, it is also important to note that in all villages, some farmers implemented the trials over a larger area than recommended, demonstrating their great interest in this agroecological technology.

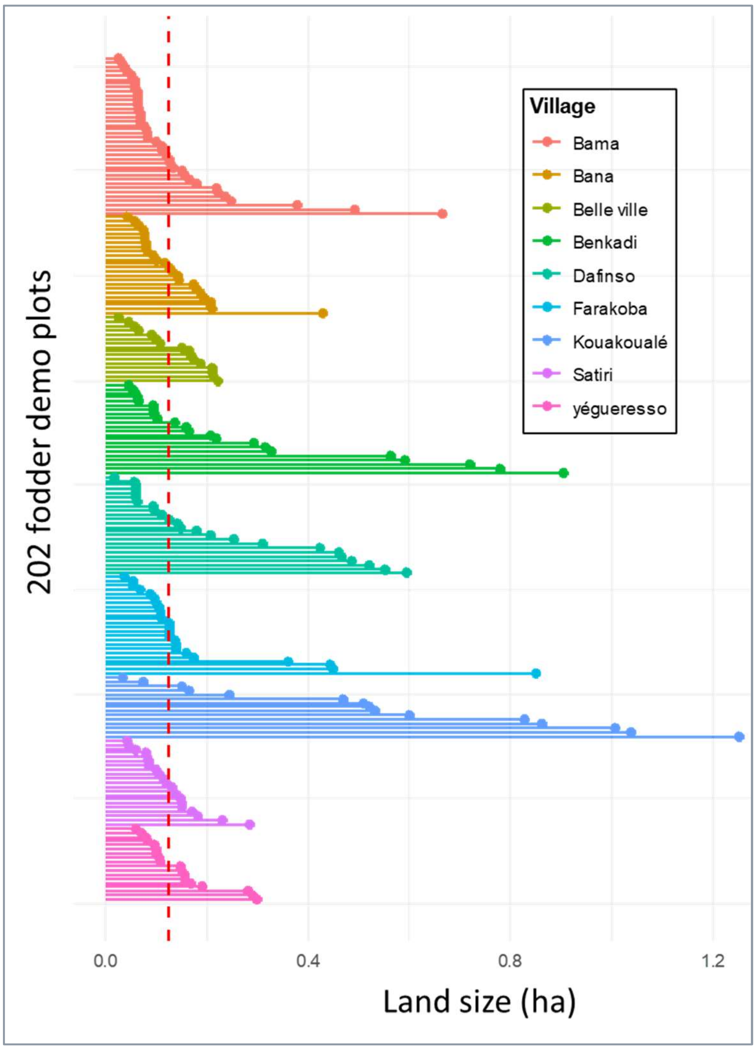

Figure 8. Areas allocated to Fodder Demo-Plots by experimenters. The dotted vertical line represents the Fodder Demo-Plot area recommended following the co-design workshops (ie: 0.125 ha).

3.1.2. Agronomic performance

3.1.2.1. Productivity dimension: grain yields and forage biomass yields

In terms of forage biomass, cereals produced a median value of 2,500 kg/ha of straw and legumes around 1,500 kg/ha of tops (Figure 9). Given the high biomass constraints in the region, this is a significant amount of biomass to help dairy farmers cope with feed shortages during the dry season, if they can store it properly.

The Figure 9 also shows significant cereal and legume grain production, which is a key result in the co-design process, as seed access and distribution are essential for forage plots.

Finally, the box plots in Figure 9 reveal great variability in biomass and grain yields, reflecting a wide range of growing conditions and management practices. Indeed, in-depth analysis of practices revealed, for example, that input levels and pest control methods for weed control differed greatly from one experimenter to another (despite the instructions and recommendations given at the outset), and that this affected biomass and grain yield.

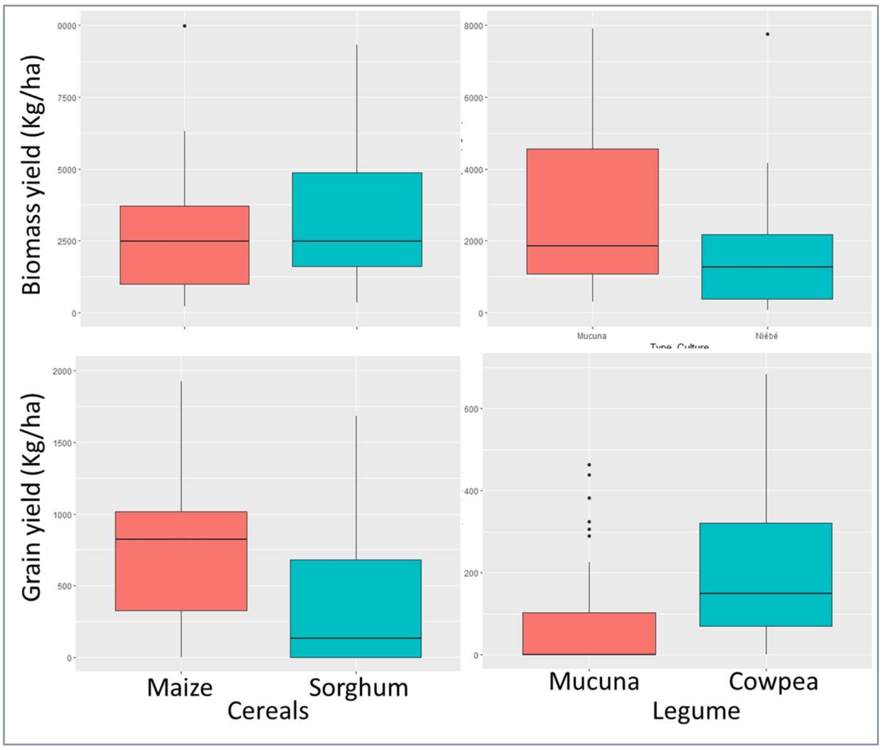

Figure 9. Main agronomic performances (grain and biomass production) of Fodders Demo-Plots

3.1.2.2. Size of agricultural inputs: use of pesticides and mineral fertilizers

3.1.2.2.1. Use of pesticides

Almost three quarters of the plots were managed without the use of pesticides. The main reason declared by farmers for using pesticides was the observation of pest attacks in the field, or because it was recommended to use a pesticide with this crop. Pesticides were mainly used on cowpea, a crop known locally to attract pests (Figure 11).

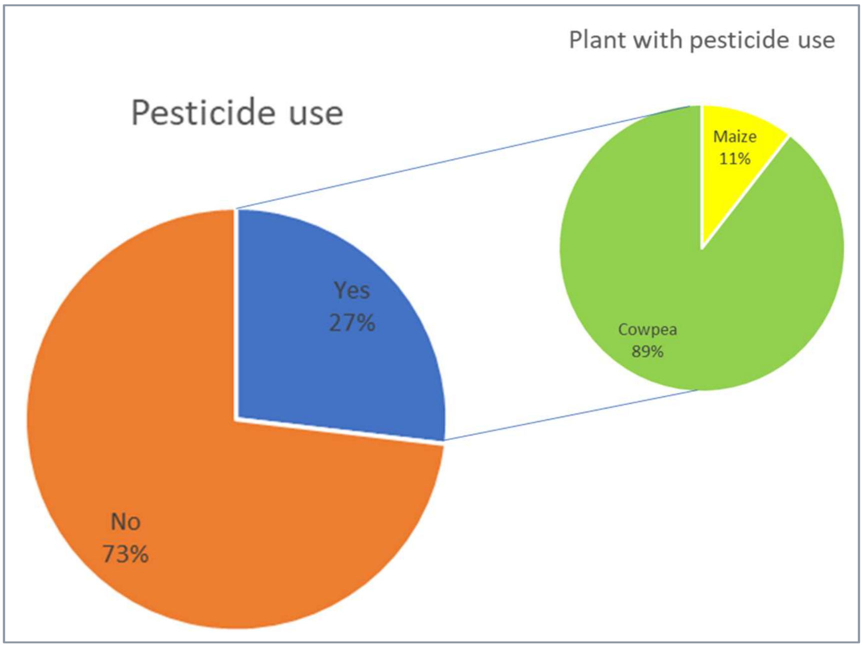

Figure 10. Pesticide use on Fodder Demo-Plots by pesticide users

3.1.2.2.2. Use of mineral fertilizers

Most of the Fodders Demo-Plots received no mineral fertilizer (148 out of 202), as the aim of the trials was to optimize the use of manure. The Figure 11 below shows the level of mineral fertilizer use and the crops concerned for the 54 farmers who reported using mineral fertilizers. The high doses of mineral fertilizers mainly concern the two cereal crops, which do indeed require high nutrient inputs. It is interesting to note that, as far as low doses are concerned, we can observe on the Figure 11 that cowpea is concerned, even though it is a legume that fixes nitrogen through symbiotic fixation.

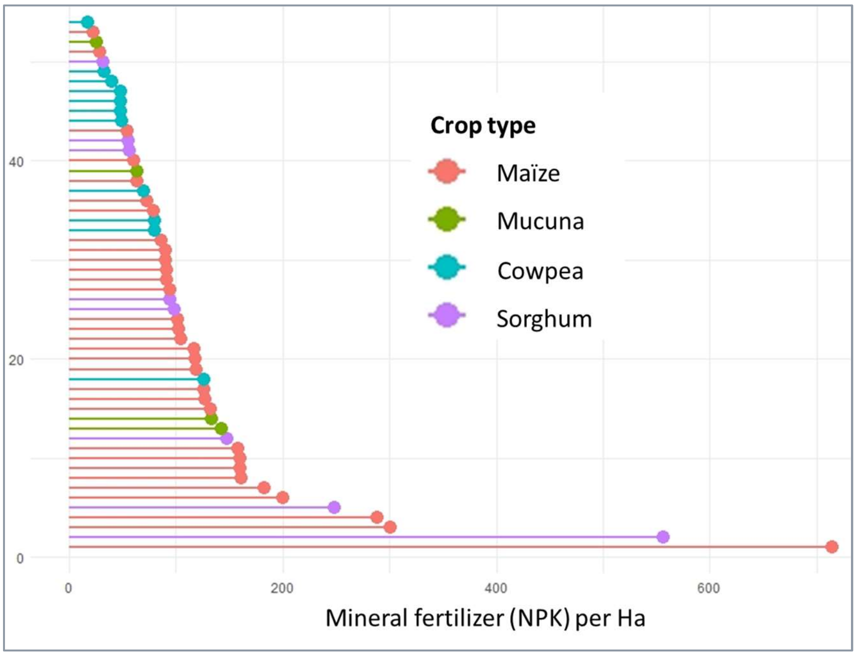

Figure 11. Use of mineral fertilizers on the 54 Fodder Demo-Plots of experimenters using mineral fertilizers

3.1.3. Socio-economic dimension

As shown in Figure 12 expenditure on cereal production (maize and sorghum) is higher than on legumes (cowpea and mucuna). This is because cereals are very demanding in terms of fertilizers, particularly maize, which generally accounts for the bulk of expenditure. This is why it makes sense to improve and increase manure production on a dairy farm scale.

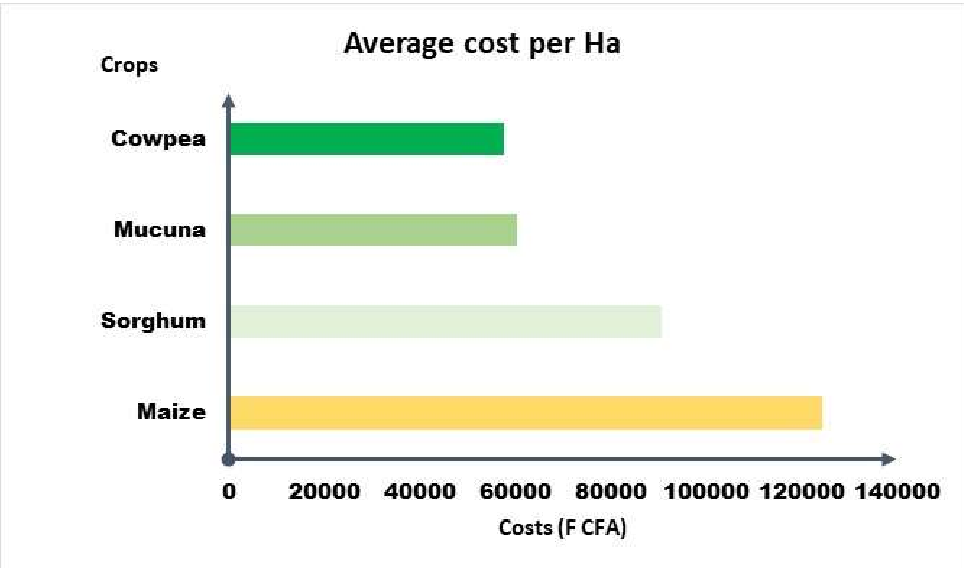

Figure 12. Average production costs for crops grown on Fodder Demo-Plots

3.1.4. Quantity of seeds reserved from Fodders Demo-Plots

The quantity of seed reserved was far greater than the quantity of seed received at all the Milk Collection Centers for all the Fodders Demo-Plots. The quantities of cereal seed reserved were greater than those for legumes, as cereals have a much higher grain yield than legumes. For dairy farmers, the quantities of seed reserved were 55.15 ± 31.3; 31.55 ± 30.83; 18.07 ± 31.61 and 13.47 ± 11.54 kg/FDP respectively for maize, sorghum, mucuna and cowpea (Table 6). Farmers reserved larger quantities of seed: 110.29 ± 47.81; 40.16 ± 17.61; 17.69 ± 11.48 and 8.02 ± 1.53 kg/FDP respectively for maize, sorghum, cowpea and mucuna (Table 7).

Table 6. Management of seeds produced by dairy farmers aggregated by Milk Collection Center

Milk collection centers	Seed received (kg)	Reserved seeds (kg)	Seed reservation rate (%)	Reserved corn seed (kg/FDP)	Mucuna seeds reserved (kg/FDP)	Reserved cowpea seed (kg/FDP)	Sorghum seeds reserved (kg/FDP)
Bama	94.5	461.61	488	24.04 ± 33.11	9.95 ± 15.13	2.96 ± 4.1	24.72 ± 35.89
Bana	63	268.13	426	27± 24.1	0.33 ± 0.82	8.12 ± 14.06	9.23 ± 13.02
Beautiful city	67	639.11	954	38.35 ± 35.56	22 ± 20.78	11 ± 8.76	99.67 ± 160.6
Benkadi	97.5	707.05	725	100.33 ± 75.9	5.33 ± 10.76	16.44 ± 24.89	51.11 ± 45.37
Dafinso	42	390.47	930	45.39 ± 37.25	14 ± 26.68	12.82 ± 8.1	29.6 ± 11.33
Farakoba	63	418.4	664	47.62 ± 43.39	6.4 ± 9.96	5.85 ± 4.57	11.91 ± 18.45
Kouakoualé	85.58	665.11	777	112.99 ± 42.4	100.3 ±122.5	41.81 ± 44.9	----
Satiri	63	381.98	606	40.11 ± 23.27	2.5 ± 1.91	15.53 ± 12.17	10.73 ± 14.20
Yégueresso	42	246.18	586	60.51 ± 58.45	1.75 ± 2.87	6.71 ± 7.77	15.4 ± 14.71
Total	617.58	4 178.04	684	55.15 ± 31.3	18.07 ± 31.61	13.47 ± 11.54	31.55 ± 30.83

Legend: ... = no data available

Table 7. Management of seeds produced by farmers aggregated by Milk Collection Center

Milk collection centers	Seed received (kg)	Reserved seeds (kg)	Seed reservation rate (%)	Reserved corn seed (kg)	Mucuna seeds reserved (kg)	Reserved cowpea seed (kg)	Sorghum seeds reserved (kg)
Bama	31	326	1052	110 ± 14	10 ± 00	17.99 ± 21.69	60 ± 00
Benkadi	16	105	656	----	----	104.66 ± 00	---
Dafinso	16	442	2763	169 ± 43.84	8.33 ± 11.78	17.33 ± 1.88	26.4 ± 9.79
Farakoba	8	30	375	----	----	30.35 ± 00	----
Kouakoualé	31	62	200	----	0	16.67 ± 20.82	12 ± 00
Yégueresso	34	118	347	51.88 ± 20.90	7.33 ± 00	3.66 ± 5.18	----
Total	136	1083	899	110.29 ± 47.8	8.02 ± 1.53	17.69 ± 11.48	40.16 ± 17.61

Legend: --- = no data

3.2. Smart management of crop and livestock co-products using the *CoProdScope* tool

3.2.1. Characterization of surveyed farms

The population studied was made up of farmers holding 49.3 ± 27.6 UBT (Tropical Livestock Units = 1 UBT is equivalent to a 250 kg bovine) per farm at the time of the assessment (year N). At the time of consulting (year N+1), the forecast herd size was 47.2 ± 28.4 LU/farm. Livestock consisted mainly of cattle, sheep and goats. The area farmed per holding was 2.84 ± 1.45 ha. For year

N+1, the forecast area was 3.82 ± 2.59 ha. The herd size decreased from year N to year N+1, and the cultivated area increased from year N to year N+1. The decrease in herd size is due to the fact that forecast animal outflows (sales, mortalities, losses) were higher than forecast animal inflows (births, purchases). The increase in cultivated area is linked to the introduction of Fodder Demo-Plots. Within these farms, family labor is the most used, with 5 ± 3.8 individuals per farm. Permanent salaried workers number 1.5 ± 1.18 per farm. The availability of livestock equipment on these farms is shown in Table 8.

Table 8. Characterization of farms surveyed with CoProdScope

Variables	Terms and conditions	Max	Avg	Min
Labor/operations	Family workforce	10	5 ± 3.8	0
	Salaried workforce	3	1.5 ± 1.18	0
Rolling stock/operations	Agroecological	7	3.4 ± 2.17	1
	Non-agroecological	6	1.9 ± 1.52	1
Forage/farm storage equipment	Hangars	4	1.2 ± 1.03	0
	Windows	2	0.8 ± 0.63	0
Animal habitats/farming	Stockyard	4	1.8 ± 0.92	1
	Barn	1	0.8 ± 0.42	0
Manure operating recycling equipment	Manure accumulation areas	1	0.3 ± 0.48	0
	Manure pits	5	0.9 ± 1.52	0

Legend: Max =maximum; Avg =average; Min=minimum; CPV =crop co-products; CPA =livestock co-products; agroecological equipment = equipment powered by animal and human energy; non-agroecological equipment = equipment powered by heat engines.

3.2.2. Covering the forage needs of farms

The forage requirements of the farms were 45,971 ± 26,816 kg DM/holding for the Cold Dry Season and the Hot Dry Season in year N. These requirements fell slightly in year N+1 (43,478 ± 28,588 kg DM/holding), as the number of cattle decreased. These requirements dropped slightly in year N+1 (43,478 ± 28,588 kg DM/farm), as the herd size decreased. Plant co-products grazed and stored at farm level were 3,285 ± 1,591 kg DM in year N and 8,197 ± 8,187 kg DM following advice in year N+1. The advice given in year N+1 resulted in a greater contribution from grazed and stored crop co-products to meeting the forage requirements of the farms compared with year N. The contribution of crop co-products to forage requirements rose from 8.5 ± 5.38% to 26 ± 21% respectively from year N to year N+1 (Figure 13).

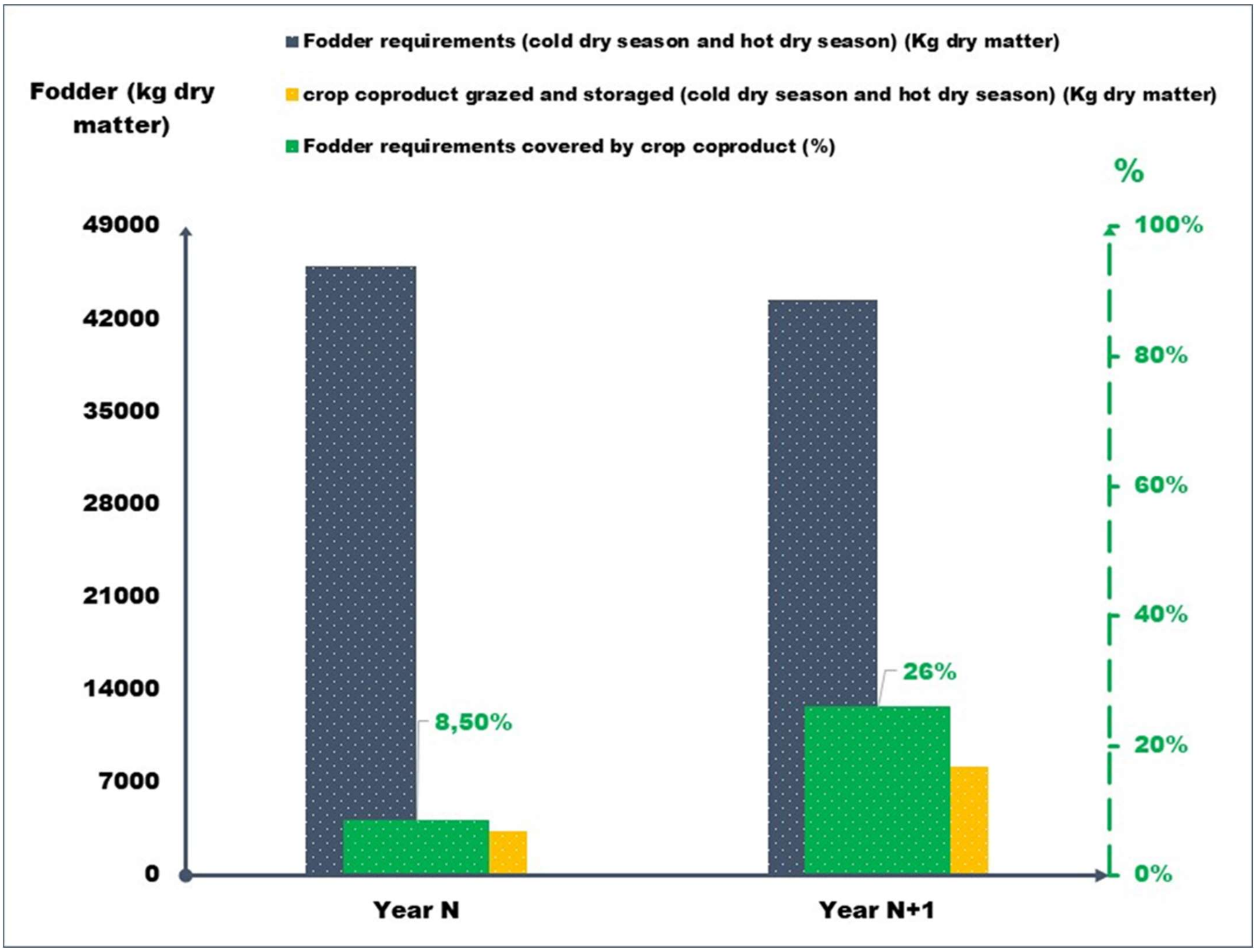

Figure *13.* **Contribution of crop co-products to meeting forage requirements on farms**

3.2.3. Covering the manure needs of farms

Farm manure requirements were 6,616 ± 3,267 kg DM/farm in year N. These requirements increased in year N+1 (9,548 ± 6,470 kg DM/farm) with the increase in cultivated area. Manure produced rose from 8,690 ± 4,476 kg DM/farm in year N, to 8,945 ± 4,835 kg DM/farm after advice in year N+1. The advice reduced the excess manure applied to the plots. The contribution of the manure produced to farm requirements fell from 141 ± 82 to 116 ± 85% for year N and year N+1 advice respectively (Figure 14). Manure production more than covered farm needs. This can be explained by the large number of livestock heads on these farms, given their small cultivated areas.

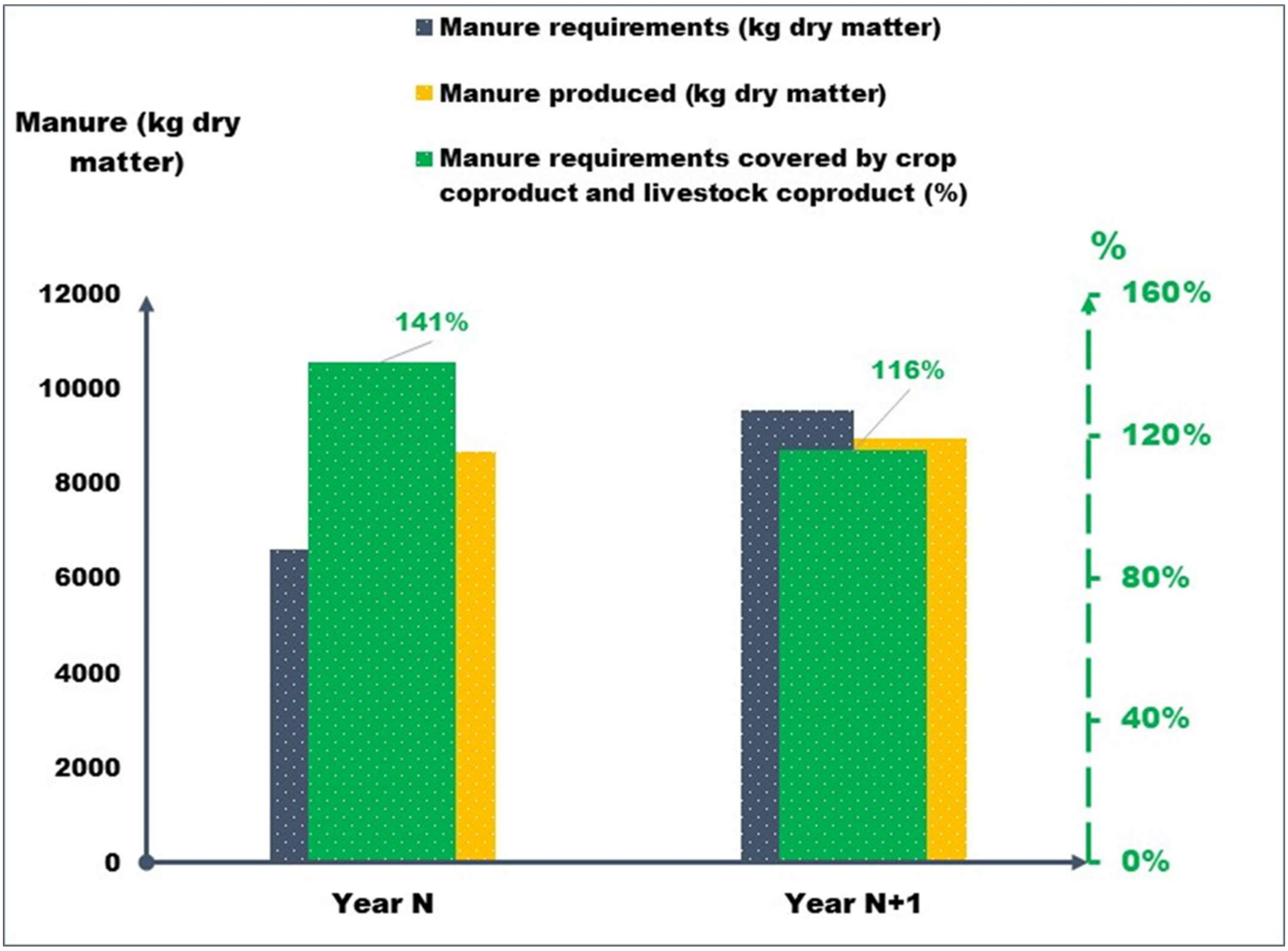

Figure 14. Contribution of manure to farm requirements

3.2.4. Covering farm mulch needs

Farm mulch requirements (light: 2 t DM/ha) were 5,685 ± 2,901 kg DM/farm in year N. These requirements increased in year N+1 (7,638 ± 5,175 kg DM/farm) with the increase in cultivated area. Plant co-products used as mulch amounted to 725 ± 1,385 kg DM/farm in year N and 791 ± 1,152 kg DM kg DM/farm in year N+1. The council was unable to improve mulch coverage in year N+1. Mulch coverage fell from 11 ± 17% to 10 ± 12% in years N and N+1 respectively (Figure 21).

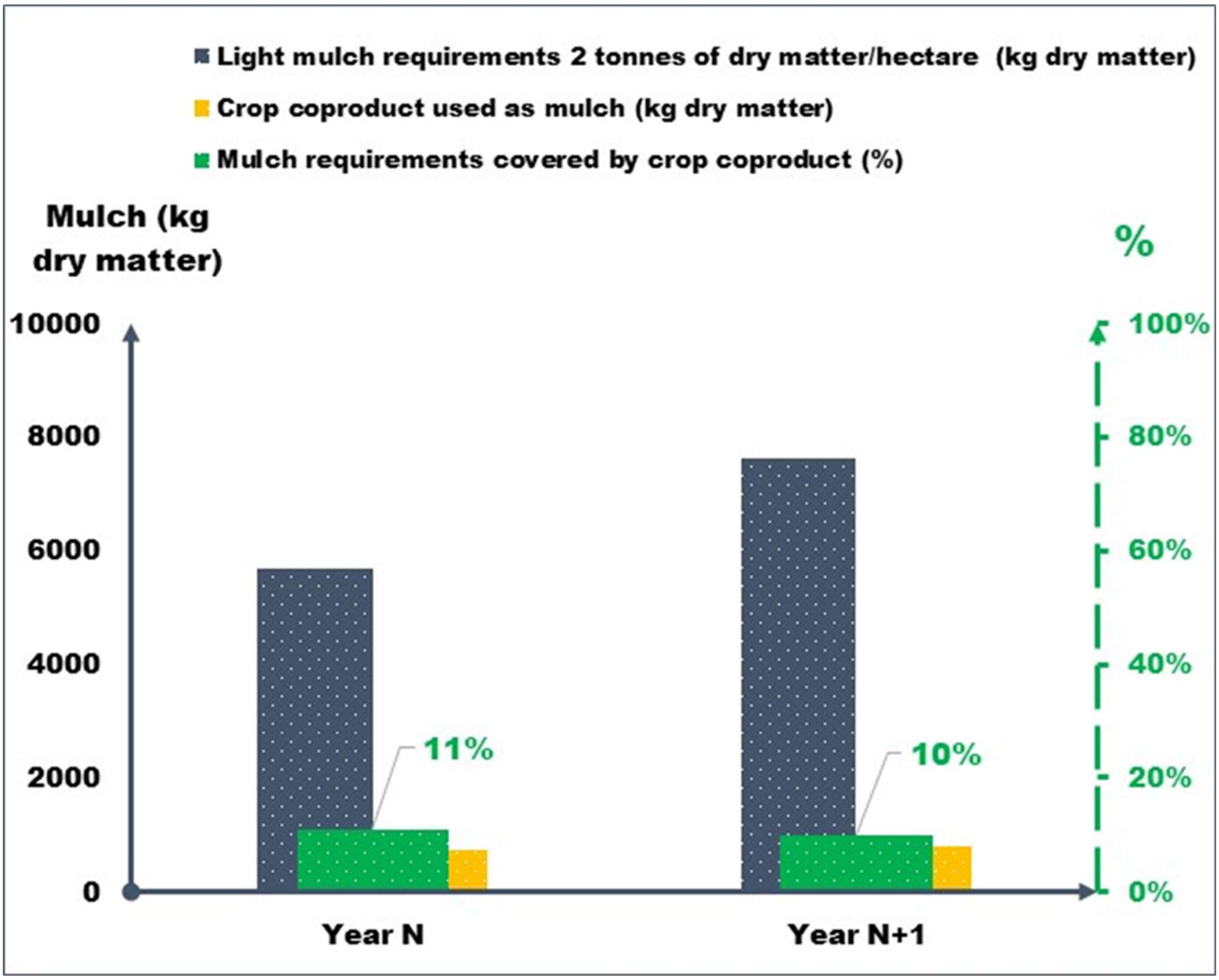

Figure 15. Contribution of crop co-products to covering farm mulch requirements

3.3. Co-design of diets using *Jabnde* and monitoring of dairy production units

3.3.1. Characterization of dairy cows

The categorization of rationed cows according to breed and type of feeding allowed us to identify three groups of animals. Group 1, with 32 zebu cows on pasture, Group 2, with 5 zebu cows in total stalls, and Group 3, with 11 crossbred cows (zebu x exotic dairy breeds) on pasture, for a total of 48 rationed cows. The zebu cows grazed and the zebu cows in total stall were older ($p < 0.5$) than the mixed cows grazed. Cows had a good general appearance, with an average Body Condition Score per cow of 3.77 ± 0.41; 3.39 ± 0.42 and 3.4 ± 0.42 respectively for pasture-fed crossbred cows, pasture-fed zebu cows and zebu cows kept in total stalls (Table 9).

Table 9. Characterization of cows monitored

Cow characterization and needs	Pasture-raised crossbred cows	Pasture-raised zebu cows	Zebu cows raised in stalls	P-value
Age (years)	4.86 ± 1.7 a	6.62 ± 1.99 b	6.6 ± 1.67 b	< 0.05
Weight (kg)	436 ± 83.2 a	242 ± 26.5 b	285 ± 92.9 b	< 0.001
Parity	2.73 ± 0.91 a	2.78 ± 1.43 a	2 ± 0.71 a	> 0.5
Body Condition Score (BCS)	3.77 ± 0.41 a	3.39 ± 0.42 a	3.4 ± 0.42 a	> 0.5
Lactation duration (weeks)	16.8 ± 13	20.3 ± 9.88	13.6 ±7.27	> 0.05
UFL requirements (Fodder Units Milk)	11.8 ± 2.77 a	5.26 ± 0.54 b	4.8 ± 1.09 b	< 0.001
PDI (Digestible Protein) requirements	902 ± 205 a	336 ± 36.4 b	353 ± 63.2 b	< 0.001
Potential dry matter requirements (kg)	13.5 ± 1.83 a	8.47 ± 0.49 b	9.1 ± 1.46 b	< 0.001
Water requirements (L)	106 ± 22.8 a	82.1 ± 107 a	73.2 ± 11.1 a	> 0.05

Legend: different letters on the same line indicate a significant difference ($p < 0.001$).

3.3.2. Analysis of cow feeding systems

No significant difference ($P > 0.05$) was observed between planned, distributed and ingested feed quantities for all cows monitored, although distributed quantities were slightly higher than planned. The diet distributed to crossbred cows on pasture consisted of 6.62 ± 3.59 and 11.1 ± 3.65 kg Gross Matter (GM)/day/cow respectively for forage and concentrates, with a grazing time of 2.24 ± 0.43 hours/day/cow. For zebu cows grazed on pasture, the diet distributed consisted of 2.73 ± 2.11 and 2.49 ± 0.79 kg GM/day/cow respectively for forage and concentrates, with a grazing time of 7.7 ± 2.55 hours/day/cow. For zebu-type cows in total stalling, the diet distributed consisted of 7.84 ± 2.38 and 1.61 ± 1.52 kg GM/day/cow for forage and concentrates respectively. In general, for co-designed diets, coverage of energy need requirements was lower compared with coverage of protein requirements (Table 10).

Table 10. Summary of co-designed diets for the three types of milking cows monitored

Assessment of co-designed diets	Pasture-raised crossbred cows	Pasture-raised zebu cows	Zebu cows raised in stalls	P-value
Coverage of energy needs (UFL/d/cow)	- 0.64 ± 0.59 a	0.009 ± 0.22 b	0.36 ± 0.53 c	< 0.001
Coverage of protein needs (PDI/d/cow)	280 ± 104 a	193 ± 91 b	162 ± 72 b	> 0.5
Ingestion (kg dry matter/cow)	15.1 ± 3.22 a	7.65 ± 1.43 b	8.02 ± 1.77 b	< 0.001
Manure (kg dry matter/day/cow)	5.76 ± 1.01 a	3.64 ± 0.35 b	3.79 ± 0.82 b	< 0.001
CH4 production (grams/day/cow)	36.91 ± 7.29 a	20.1 ± 2.21 b	----	< 0.001

Legend: ---- = No data (*Jabnde* does not calculate potential CH4 production for totally stalled animals); different letters on the same line indicate a significant difference (p < 0.001). UFL : Unité de Fourrage Lait in french ; PDI : protéines digestibles dans l'intestin in french

3.3.3. Milk production level of rationed cows

Milk production from crossbred cows on pasture was 10.7 ± 2 L/day/cow. This was significantly higher than for pasture-fed Zebu-type cows and total-stall Zebu-type cows, which produced 1.05 ± 0.52 and 1.55 ± 0.55 L/day/cow respectively. For crossbred cows on pasture, the milk production obtained (10.7 ± 2 L/day/cow) was identical (P> 0.5) to the desired production of 10.5 ± 4.28 L/day/cow. For zebu cows grazed on pasture, the milk production obtained (1.05 ± 0.52 L/day/cow) was lower (P < 0.001) than the desired production of 1.77 ± 0.7 L/day/cow. For zebu-type cows in total stalling, the milk production obtained (1.55 ± 0.55 L/day/cow) was identical (P> 0.05) to the desired production, which was 1.7 ± 0.45 L/day/cow (Figure 16).

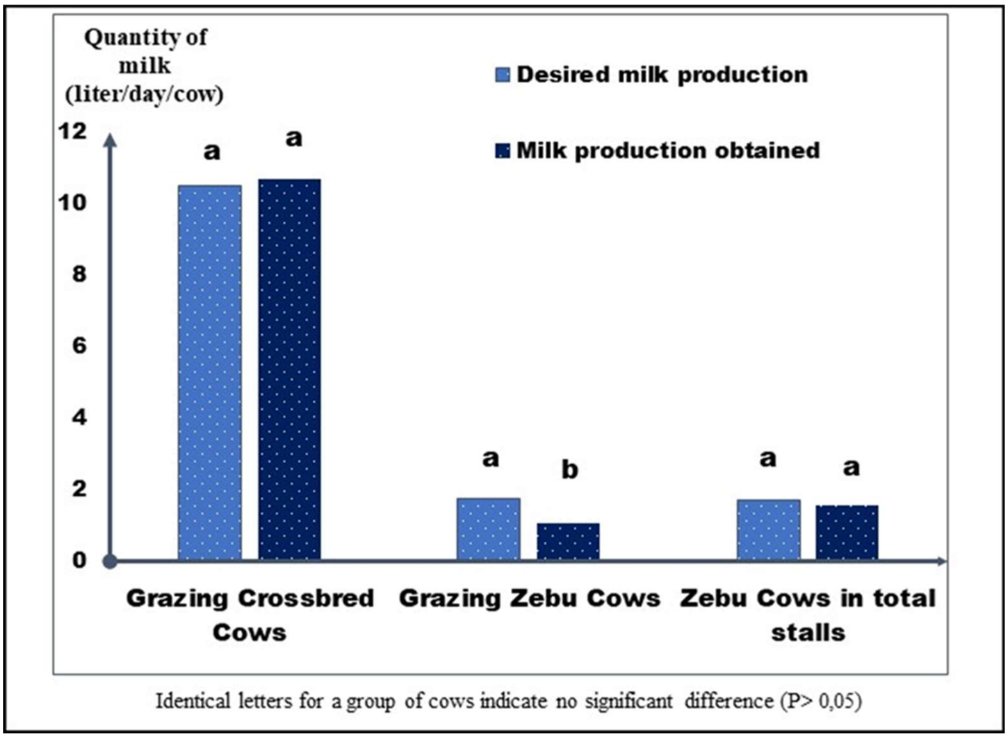

Figure 16. Average milk production for the three types of cows monitored

3.3.4. Analysis of the perceptions of volunteer farmers who tested diets co-designed with *Jabnde*

For all cows monitored, volunteer farmers indicated that the production target had been fully achieved for 27.1% of cows. However, significant differences were observed between zebu cows kept on pasture, those kept in total stall and crossbred cows kept on pasture. In the case of zebu cows (grazed and totally stalled), the milk production target was fully achieved by 9.40% and 40% of cows respectively. For crossbred cows, the production target was fully met for 72.7% of cows.

The milk production targets were achieved thanks to: (i) the balanced diet co-designed with *Jabnde*; (ii) the supply of quality forage and (iii) the supply of concentrated feed. As for the failure to reach production targets, this can be explained by: (i) poor forage quality; (ii) poor health status of the animal; (iii) late stage of lactation; (iv) refusal to consume certain feeds; (v) and various other reasons (weakened cow at start of experiment, distant watering source, calving rank for primiparous cows).

Although only 27.1% of cows achieved the desired milk production, volunteer farmers were partially satisfied with the level of production achieved for 79.20% of cows. Figure 17. They felt that the milk production achieved was finally quite close to that desired for 100; 73 and 69% of cows respectively for stalled zebus, crossbreds and pasture-raised zebus. Also, the volunteer farmers stated that they would not have achieved the quantity of milk produced without the rationing carried out with *Jabnde* for all cows (100%).

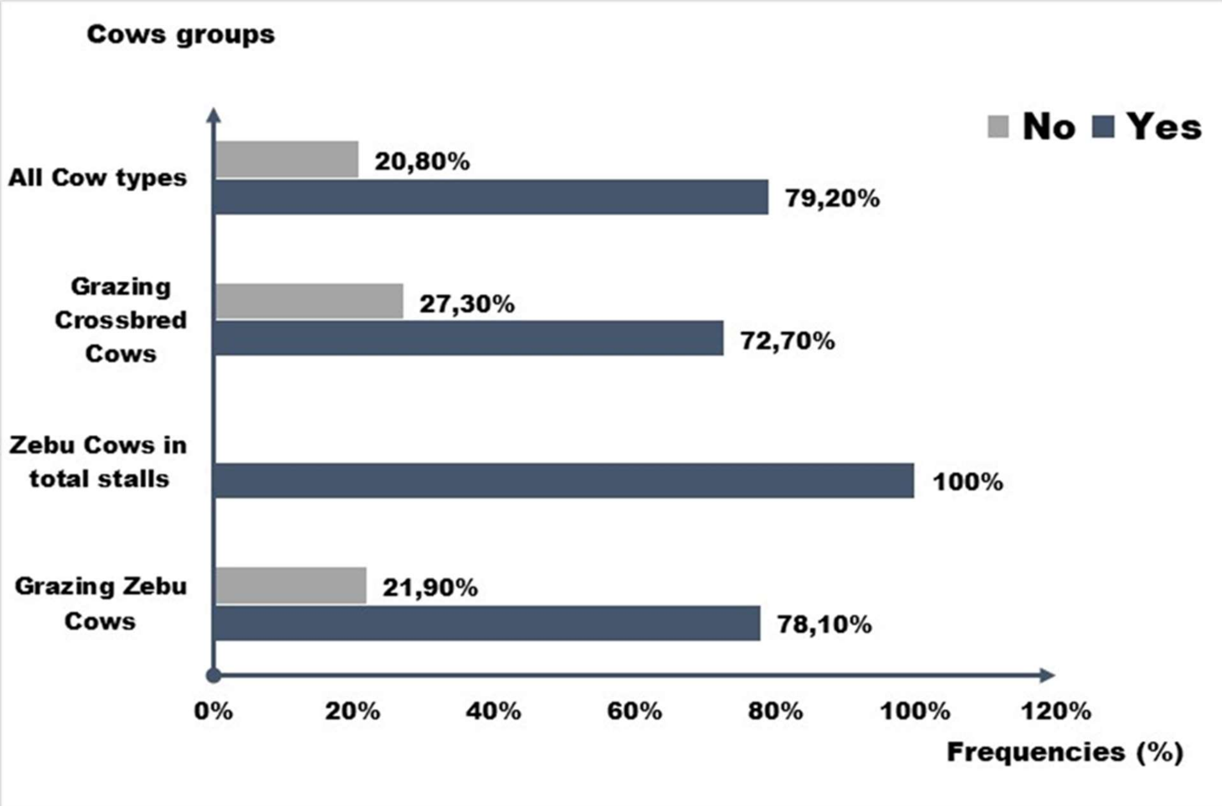

Figure 17. Satisfaction of volunteer farmers with milk production for the three types of cows monitored

All the volunteer farmers felt that using Fodder Demo-Plots in the diet reduced their concentrate use considerably. However, 65% of volunteer farmers felt that the use of Fodders Demo-Plots had increased their workload, particularly in harvesting (69.23%) and production (46.15%). The level of work increase was strong for a proportion of 61.54% of volunteer farmers who felt that the use of Fodders Demo-Plots had increased work.

3.4. Preliminary results of the implementation dynamic of Efficient Covered Manure Pits

The Efficient Covered Manure Pits were installed on gravel (73.68%), sand (21.05%) and clay (5.26%) soils. The majority of pits were installed in fields (47.36%). The remaining pits were installed on the concession (26.32%) or on both the concession and the field (26.32%), corresponding to farms where the houses are on the edge of the fields. They recorded a volume of 12.86 ± 4.20 m /pit.[3]

The workforce mobilized for digging and stabilizing a pit consisted of 5.11 ± 1.94 people over 6 ± 3.25 days for a duration of 8.84 ± 2.97 hours/day. The total cost of pit construction was 33,247.37 ± 19,138.56. The quantity of livestock co-products mobilized (2,823 ± 1,845.64 kg/pit) was higher ($P < 0.001$) than that of crop co-products (469.2 ± 313.15 kg/pit). The number of animals mobilized for pit filling was as follows: 12.79 ± 13.7 dairy cows; 12.89 ± 17.23 other cattle and 14.64 ± 14.69 small ruminants. The crop co-products mobilized were composed of forage and bedding refuse, coarse co-products (straw) and household refuse (peelings). The quantity of water added to accelerate co-product decomposition inside the pits was 2,822.99 ± 1,845.64 L/pit. Filling time was 102.37 ± 58.96 days/pit. Temperature measurements at three different levels revealed an increase in temperature from top to bottom. The surface temperature was 33.6 ± 5.49 °C/pit, while those measured 25 and 50 cm below the surface were 42.9 ± 8.79 and 51 ± 8.03 °C/pit respectively.

Data collection continues.

4. Agroecological assessment of technologies

4.1. Description of agroecological technologies tested

4.1.1. At plot level: Fodder Demo-Plots

Control treatment: Conventional non-fodder crops (maize, sorghum, cowpea) + low use of manure

Description: The control treatment is not part of the trial here, but reflects the current main practice in the region to feed the herd in a very constrained environment. Most farmers grow conventional non-fodder crops such as maize, sorghum or cowpea and use little manure. While these crops produce biomass in addition to grain, they are not selected to optimize biomass production, unlike forage crops. Alternative technologies at plot level are therefore crop varieties (legumes and cereals) selected to optimize biomass production, the key objective for biomass-constrained livestock owners.

Agroecological technology 1: Cereal forage crops (maize, sorghum) + large quantities of manure

Description: This technology, like the following one, has been implemented on the farm according to conditions and farmers' access to mechanization, mineral fertilizers, labor, pesticide use, etc. Cereal forage crops are a very promising technology in the region, as they have a high capacity to generate biomass if sufficient inputs are provided, which also explains why the technology is being tested with increased use of manure. The only condition was to grow the feed grain on at least 0.125 ha. The maize variety was "Maïs Espoir" and the sorghum variety "Grinkan". Farmers received 3 kg and 1.5 kg of seed for maize and sorghum respectively. The cereal forage crops tested in Burkina Faso are illustrated in Figure 3. For each cereal forage plot, 2/3 of the land was dedicated to forage production and the remaining 1/3 to seed production. This seed production was then divided into 3: (i) one third to replicate the demonstration plot the following year, the remaining two thirds for new farmers (baby farmers) to implement the trials the following year. Agronomic performance was measured on 4 plots of 4 m²/speculation (quadrant method). Two quantities of biomass were measured, one actually produced in the trials on the basis of these 4 samples, and the other when the biomass was collected by the farmers to assess the biomass actually available for livestock (considering farmers' biomass storage constraints).

Agroecological technology 2: leguminous fodder crops (mucuna, cowpea) + high input of manure

Description: Exactly as in Agroecological Technology 1, these trials were conducted on the farm under farmers' constraints. The minimum plot size was 0.125 ha for each forage legume (for a total of 0,5 ha for cereal and legume crops). Fodder legumes were tested as they both increase biomass production and increase soil nitrogen through symbiotic fixation. The protocol for this second agroecological technology is the same as for the first. For both alternative technologies, 202 trials have been carried out and all results are available for farming practices and grain and biomass yields.

4.1.2 At dairy farm level: Dry-season feeding practices for dairy cows

The forage crops tested in the previous section at plot level are just one type of feed for dairy cattle. To be sure of the added value of these forage crops, and of the additional biomass they provide, it was necessary to adopt a more systemic approach at dairy production unites (which is more or less at farm level and even at landscape level if we consider pastures located outside the village) and to test separate feed diets including, or not, these forage crops.

Control treatment: High use of natural pasture + use of fodder from non-fodder crops + high use of concentrates

Description: The control treatment in this case is the current cattle feed diet in the Bobo-Dioulasso region. Cattle depend mainly on pasture when it is available, on crop residues stored by farmers or grazed in other farmers' fields (free grazing is the rule in the region and cattle are allowed to graze in fields after the harvest period), and finally on concentrates such as cotton cake when no more fodder is available. This cattle diet constitutes the T0 control treatment at farm level.

Based on this observation, 3 agroecological technologies, i.e. alternative feeding strategies, were tested to optimize biomass production from forage crops and reduce dependence on pasture and concentrate feed.

Agroecological technology 1: Reduced use of pasture + use of fodder from non-fodder crops + use of fodder from cereal fodder crops + moderate use of concentrates.

Description: This agroecological technology is based on the principle that the additional biomass produced by growing feed grains will enable farmers to reduce their expenditure on concentrates (very expensive feed) and their dependence on pasture. Indeed, with the expansion of farmland, pastures are less accessible and more farmers are concentrating on them. Pasture dependency is therefore a non-resilient strategy that should be overcome by on-farm biomass production. What's more, if cows stay close to the farm with accessible biomass, the manure produced will be more easily optimized in cropland, unlike the manure deposited on pasture, considered lost to farmers (but useful for maintaining the soil fertility of these pastures).

Agroecological technology 2: Reduced use of pasture + use of fodder from non-fodder crops + use of fodder from leguminous forage crops + moderate use of concentrates.

Description: The added value of this agroecological technology is based on the same hypothesis as T1 described above (reduced use of concentrated feed and access to pasture). In addition to these added values, this agroecological technology proposes to use legumes rather than cereals to produce biomass. In doing so, this technology will not only increase biomass production, but also increase soil nitrogen through symbiotic fixation. In this environment, where access to mineral fertilizers is very limited, legumes can help to maintain soil fertility, in addition to providing significant inputs of organic matter. Last but not least, leguminous fodder crops are highly nutritious, complementing cereal fodder crops that are richer in fiber.

Agroecological technology 3: Use of fodder from non-fodder crops + use of fodder from cereal and legume fodder crops + moderate use of concentrates.

Description: In this agroecological technology, both types of forage are grown (cereals and legumes), in addition to a low use of concentrated feeds and crop residues. The quantity of biomass produced is sufficient to avoid grazing, enabling farmers to optimize manure collection and thus improve soil fertility management. To be totally self-sufficient in biomass, it is important to have enough land to grow both cereals and fodder legumes.

4.2. Specific assessment

Agroecological innovations tested: Cereals and forage legumes to increase biomass production in quantity and quality for dairy cattle feed diets.

Agroecological principles tested: synergy, diversity, recycling.

Comparative performance analysis (compared with the conventional diet) :

- Production of additional biomass to feed livestock, particularly during the dry season;
- Production of quality forage (legumes) to compensate for poor feed quality on pastures.
- Production of biomass that can be stored for use during the dry season.

Assumptions tested:

- Legumes and feed grains can be grown under farmers' conditions and generate sufficient biomass to feed dairy cattle during the dry season.
- Legumes and forage cereals are quality forages that can increase milk production without increasing production costs (compared to the conventional approach based on pasture and concentrate feed).

4.3. General assessment

The agroecological technologies tested with dairy farmers and a few farmer-members of ALL-BF in Burkina Faso were evaluated in participatory workshops (Figure 18).

Figure 18. Participatory evaluation of agroecological technologies tested with ALL member farmers in Burkina Faso

4.3.1. Assessment at plot level (forage crops)

The results of the participatory evaluation at plot level reveal a very positive assessment by farmers of the two alternative agroecological technologies studied (Table 11). Indeed, conventional practice is mainly ranked below average, due to the low biomass available if the crops grown are not specifically forage crops. Indeed, most current varieties have concentrated on grain production, to the detriment of the biomass available for livestock feed. The introduction of forage cereals makes it possible to increase this biomass production and thus obtain higher scores on all the dimensions assessed (Figure 19 and 20). This cereal crop enables both biomass and grain production to be optimized to contribute to household food security. The highest-ranked technology is leguminous forage, as it increases crop diversity and also provides high-quality fodder for dairy cows. Legumes also offer the ability to fix nitrogen in the soil, a crucial advantage in this region where farmers have very limited access to mineral fertilizers.

Table 11. Results of the participatory evaluation of conventional practices (T0) versus agroecological technologies (T1 and T2) at plot level for the 4 dimensions of agroecological transition characterization: Diversity, Synergies, Efficiency, Recycling.

Treatment	Elements	Index[1]				Element score [2]	Evaluation [3]
		I	II	III	IV		
T0: Conventional cereal crop + low use of manure	Diversity	2	1	2	1	6	37.5
T1: Cereal forage crops + high use of manure	Diversity	3	2	3	2	10	62.5
T2: Leguminous forage crops + high use of manure	Diversity	4	3	4	2	13	81.25
T0: Conventional cereal crop + high use of manure	Synergies	1	1	1	1	4	25
T1: Cereal forage crops + high use of manure	Synergies	2	2	2	2	8	50
T2: Leguminous forage crops + high use of manure	Synergies	3	1	3	3	10	62.5
T0: Conventional cereal crop + high use of manure	Efficiency	1	1	2	1	5	31.25
T1: Cereal forage crops + high use of manure	Efficiency	2	2	1	2	7	43.75
T2: Leguminous forage crops + high use of manure	Efficiency	3	3	1	3	10	62.5
T0: Conventional cereal crop + high use of manure	Recycling	1	1	3	1	6	37.5
T1: Cereal forage crops + high use of manure	Recycling	3	2	2	2	9	56.25
T2: Leguminous forage crops + high use of manure	Recycling	4	2	3	2	11	68.75

Legend: Index[1] : score from 0 to 4 for each index (I = crops; II = animals (including fish and insects); III = trees (and other perennials); IV = diversity of activities, products and services); Element score[2] : sum of index scores, ranging from 0 to 16; Evaluation[3] : (Element score/16) * 100

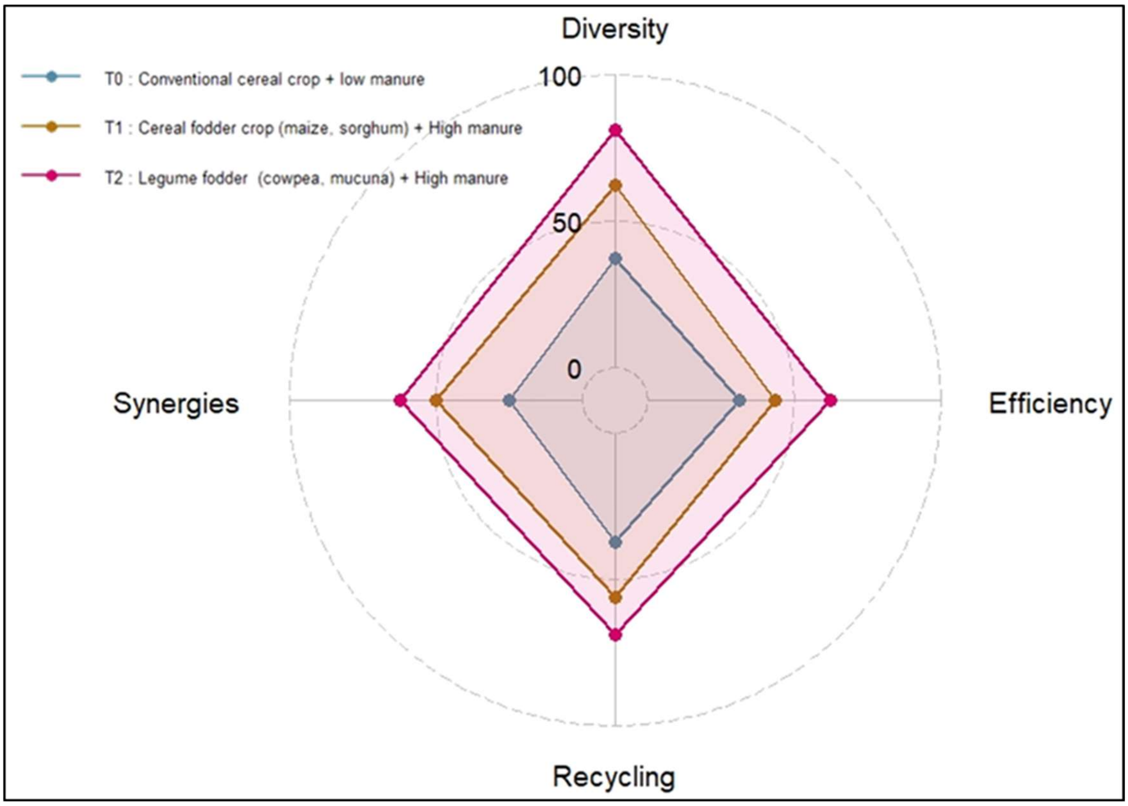

Figure 19. Results of the participatory evaluation of conventional practice (T0) and agroecological technologies (T1 and T2) at plot level for the 4 dimensions of the Characterization of the Agroecological Transition (diversity, synergies, efficiency, recycling).

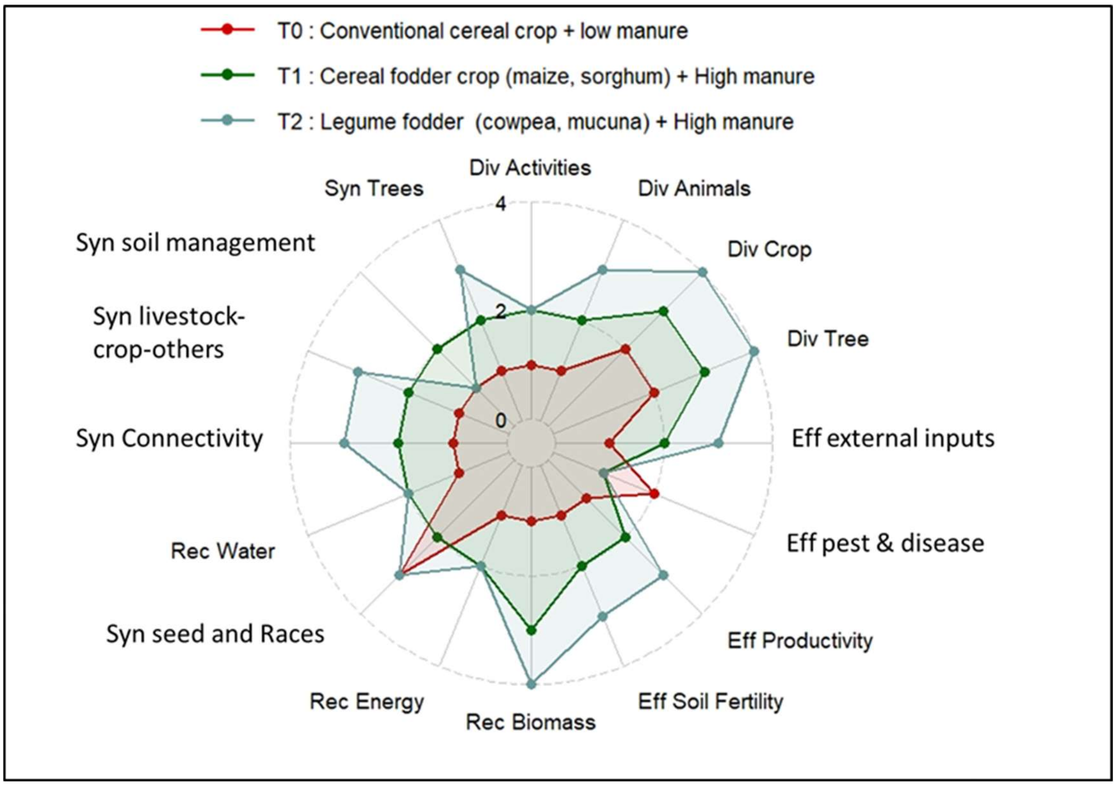

Figure 20. Results of the participatory evaluation of conventional practice (T0) and agroecological technologies (T1 and T2) at plot level at the four dimensions and sub-dimensions of the Characterization of the Agroecological Transition (diversity, synergies, efficiency, recycling).

4.3.2. Evaluation of dry-season feeding practices for dairy cows

The results of the participatory evaluation of agroecological technologies at dairy farm level provide a clear hierarchy of participants' appreciation of the 4 treatments: at the lowest rank, we find the treatment corresponding to conventional practice (T0); at the highest rank, we find the technology based on the use of fodder from non-fodder crops and a mixture of fodder from cereal and leguminous crops with low-concentrated feed (T3); and in the middle the technologies that use a single type of fodder crop fodder (leguminous T2 or cereal T1) in addition to fodder from non-fodder crops and low-concentrated feed (Table 12 and 13). The Figure 21 and 22 show that T1 and T2 have identical raking on most dimensions, always better than conventional practice. The combination of these two forage types, represented by T3, clearly shows the highest rank, as it combines (i) the ability of legumes to fix nitrogen and produce biomass and (ii) the ability of cereal crops to produce cereal grains for household food security and produce quality biomass to feed cows. These results, at the scale of the milk production unit (and virtually at farm level, so to speak), show that expectations of agroecological technologies are not concentrated on a single dimension, but that they must enable high performance to be achieved in different aspects of the farming system.

Table 12. Results of the participatory evaluation of conventional practices (T0) and agroecological technologies (T1, T2, T3) at dairy farm level for the 4 dimensions of the Characterization of the Agroecological Transition, Part 1: Diversity, synergies, etc.

Treatment	Elements	Index[1]				Element score [2]	Evaluation [3]
		I	II	III	IV		
T0: Pasture, crop residues, concentrated feed	Diversity	1	2	2	1	6	37.5
T1: Low pasture, crop residues, cereal forage, few concentrates	Diversity	2	3	3	2	10	62.5
T2: Low pasture, crop residues, leguminous forage, few concentrates	Diversity	2	3	3	2	10	62.5
T3: Crop residues, leguminous and cereal forage, few concentrates	Diversity	3	4	4	4	15	93.75
T0: Pasture, crop residues, concentrated feed	Synergies	1	2	2	2	7	43.75
T1: Low pasture, crop residues, cereal forage, few concentrates	Synergies	3	2	2	3	10	62.5
T2: Low pasture, crop residues, leguminous forage, few concentrates	Synergies	3	1	2	3	9	56.25
T3: Crop residues, leguminous and cereal forage, few concentrates	Synergies	3	1	3	4	11	68.75

Legend: Index[1] : score from 0 to 4 for each index (I = crops; II = animals (including fish and insects); III = trees (and other perennials); IV = diversity of activities, products and services); Element score[2] : sum of index scores, ranging from 0 to 16; Evaluation[3] : (Element score/16) * 100

Table 13. Results of the participatory evaluation of conventional practices (T0) and agroecological technologies (T1, T2, T3) at dairy farm level for the 4 dimensions of the Characterization of the Agroecological Transition, Part 2: Efficiency, Recycling, etc.

Treatment	Elements	Index[1]				Element score [2]	Evaluation [3]
		I	II	III	IV		
T0: Pasture, crop residues, concentrated feed	Efficiency	1	2	1	1	5	31.25
T1: Low pasture, crop residues, cereal forage, few concentrates	Efficiency	2	2	1	2	7	43.75
T2: Low pasture, crop residues, leguminous forage, few concentrates	Efficiency	2	2	2	2	8	50
T3: Crop residues, leguminous and cereal forage, few concentrates	Efficiency	3	3	1	3	10	62.5
T0: Pasture, crop residues, concentrated feed	Recycling	1	1	2	1	5	31.25
T1: Low pasture, crop residues, cereal forage, few concentrates	Recycling	2	2	3	2	9	56.25
T2: Low pasture, crop residues, leguminous forage, few concentrates	Recycling	3	2	3	2	10	62.5
T3: Crop residues, leguminous and cereal forage, few concentrates	Recycling	4	4	2	4	14	87.5

Legend: Index[1] : score from 0 to 4 for each index (I = crops; II = animals (including fish and insects); III = trees (and other perennials); IV = diversity of activities, products and services); Element score[2] : sum of index scores, ranging from 0 to 16; Evaluation[3] : (Element score/16) * 100

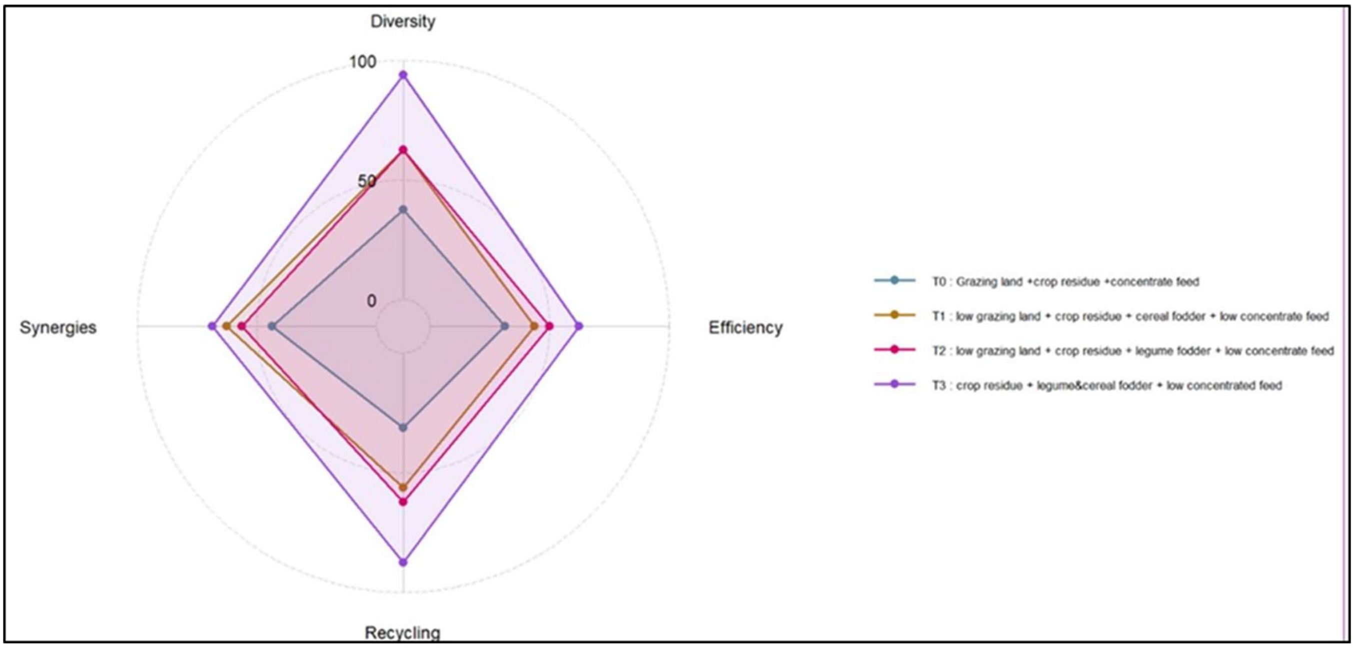

Figure 21. Results of the participatory evaluation of conventional practices (T0) and agroecological technologies (T1, T2, T3) at dairy farm level for the 4 dimensions of agroecological transition characterization (diversity, synergies, efficiency, recycling).

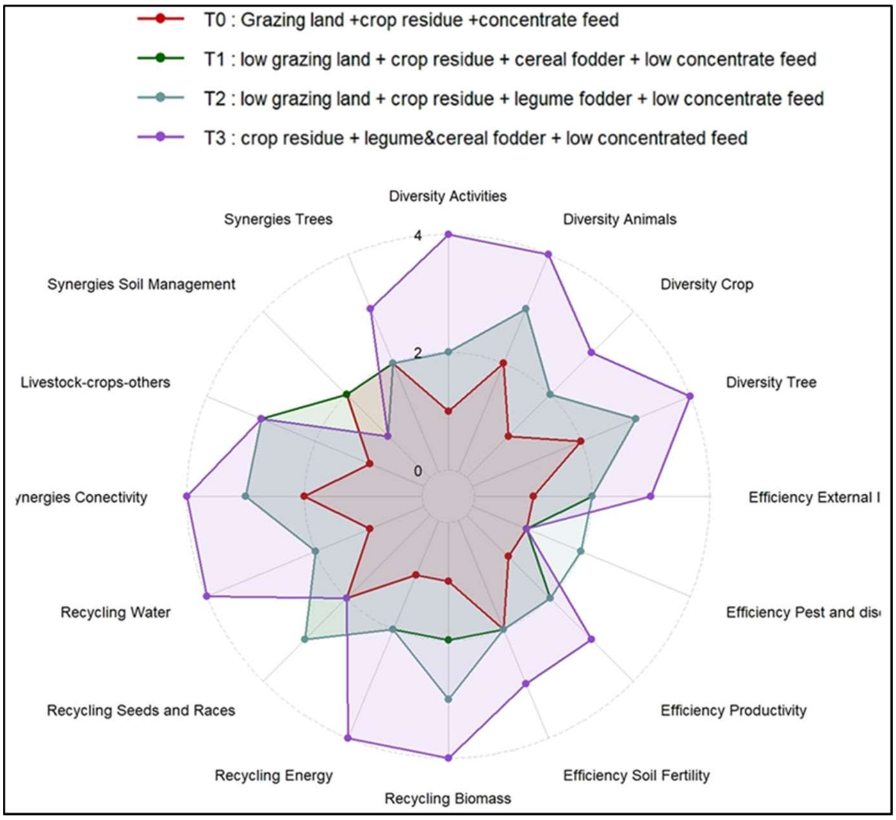

Figure 22. Results of the participatory evaluation of conventional practice (T0) and agroecological technologies (T1, T2, T3) at dairy farm level at the four dimensions and sub-dimensions of the Characterization of the Agroecological Transition (diversity, synergies, efficiency, recycling).

5. Potential for adaptation and adoption of tested technologies

5.1. Fodder Demo-Plots

The dynamic forage and forage seed production system tested as part of the CGIAR agroecological initiative was accepted by 90.28% of volunteer farmers during the 2023/2024 experimentation campaign and enabled the production of forage and seed that was mobilized to re-establish the system during the 2024/2025 campaign. This system has improved forage availability at farm level and popularized the practice of forage cultivation. The main difficulties encountered with the Fodder Demo-Plots have been protecting the plots from animals, pockets of drought and crop pest attacks, and the difficulty farmers have in conserving and storing seeds properly. Out of a forecast of 130 volunteer girl farmers to perpetuate the FDP dynamic during the 2024/2025 cropping season, we recorded 135 volunteers, i.e. a surplus of 5 farmers (Ouattara et al., 2024c).This indicates the interest of farmers in this technology and therefore probably its suitability for local dairy production. The mid-term follow-up of Mother and Babie volunteer farmers for this new campaign revealed that 97% and 76% of Mother and Babies farmers had implemented at least one forage crop on their own, without any need for rigorous monitoring by the research team in charge of follow-up. We can therefore say that the road to adoption is fairly well mapped out. The technology is mature enough to be scaled up. However, in view of the heterogeneity of the quantities of forage and seed produced across the sample of volunteers, it is still necessary to support farmers in setting up forage crops and the cooperative system for sharing forage seed.

5.2. Using the *CoProdScope* tool to manage farm co-products

The AEI enabled the *CoProdScope* tool to be tested on dairy farms in the Bobo-Dioulasso dairy basin, in order to carry out production and co-product management assessments and to advise farmers on how to manage these co-products more efficiently as a stock of fodder, manure and mulch for their farms. Its usefulness was appreciated by the volunteer farmers. It made them aware of the need for better management of their farms, given the quantities of manure they were losing during animals mobilities. The tool also enabled them to have a clear idea of the fodder available on the farm for the coming dry season (when fodder resources are unavailable), and to take steps to improve this availability. The absence of registers on the farms was the main constraint to the construction of the balance sheet, as farmers had to put a lot of thought into providing the data. Also, one of the limitations of the version of the tool tested (Excel office version) is that it is not very ergonomic. However, the mobile application version currently being finalized should make the tool easier to use. To further disseminate the technology, we used it with 30 farmers during the 2024/2025 experimentation campaign.

5.3. Using the *Jabnde tool* to diet cows

All the volunteer farmers who tested the *Jabnde* tool felt that it was a good tool for improving cow milk production and income. The volunteer farmers stated that they would not have achieved the quantity of milk produced without the rationing adjustment enabled by *Jabnde* for all cows (100%). The majority of volunteer farmers (90%) replied that the quantity of milk milked from cows rationed using *the Jabnde* tool was greater than that from other cows. As with *CoProdScope*, the version of the *Jabnde* tool used requires the presence of a technician, which remains a limit to the autonomy of farms in its use. Thinking about a version that can be easily used by farmers could facilitate its adoption. We plan to reuse the tool with 20 girl farmers during the 2024/2025 experimentation campaign. This tool is adapted to the characteristics of Burkina Faso's dairy production units, and is appreciated by the people in charge of these dairy production units. In the future, it will be necessary to carry out a follow-up to see if the farmers manage to apply the rationing advice, and also to co-design with the farmers diets adapted to groups of homogeneous cows, given that *Jabnde* elaborates individual diets.

5.4. Efficient covered manure pits

At the time of writing, 59% of volunteer farmers have been able to set up manure pits properly (from construction to covering after filling). During the workshop to identify the "Outcomes" induced by AEI in the Bobo-Dioulasso dairy value chain, farmers revealed that covered manure pits enabled them to produce quality manure that improved soil fertility over the long term, and thus improved fodder yields. They did, however, highlight the fairly heavy workload involved, particularly in building the pits and removing the manure once it has matured. The Figure 23 highlights the workload. To further disseminate the technology, 42 volunteer girl farmers have been identified to set up a manure pit during the 2024/2025 crop year. They are being supported in this process. Of these 42 farmers, 6 mother farmers have applied. Given the workload involved, this technology will be better adopted by men. We need to continue monitoring the pits to see whether they have been adopted.

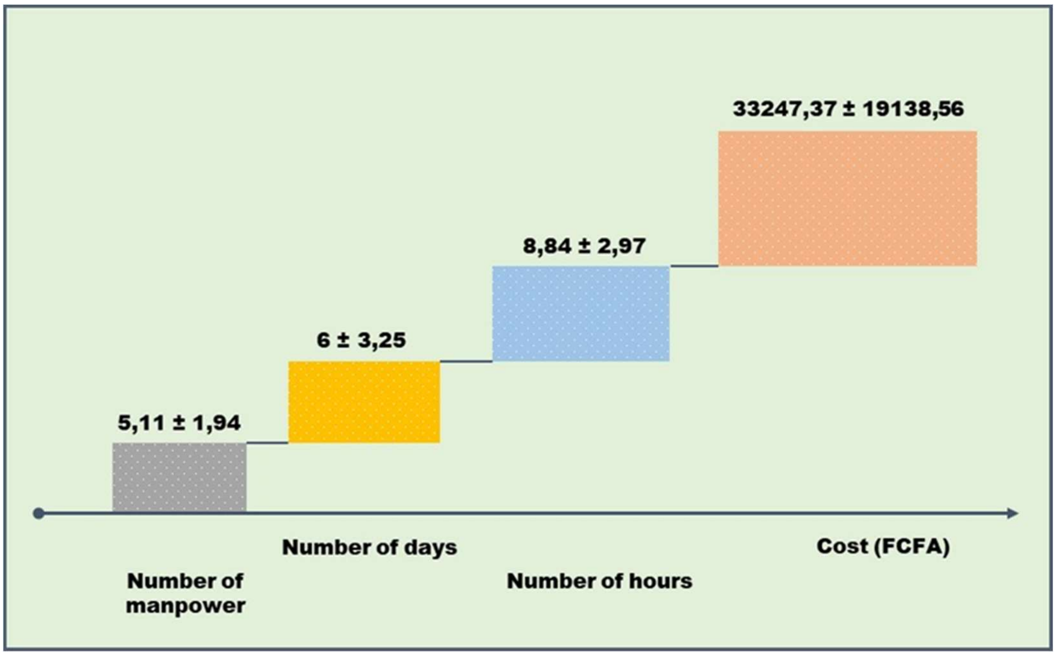

Figure 23. Costs associated with the installation of an efficient covered manure pit

6. Reflections, lessons and recommendations

6.1. Reflections, lessons learned and recommendations on how to initiate and conduct the design process and general methodological considerations

General reflections on the usefulness of the design process implemented from the point of view of the various stakeholders: (1) international researchers (CIRAD/CIRDES/INERA), (2) national partners (DIP/ALL Burkina Faso)

The process of co-designing, testing and assessing agroecological technologies implemented by the project team in Burkina Faso has enabled the research institutions (CIRAD, CIRDES and INERA) to pursue a momentum in the local dairy value chain that began in 2020 with the creation of the Dairy Innovation Platform of Bobo-Dioulasso as part of the Africa-Milk project. For the researchers, the OnEDA approach, which co-design, experiments and assess with the dairy farmers agroecological technologies, has made it possible to set up a sequence of practices in time and space, putting into practice and in full scale the agroecological principles of interaction between agriculture and livestock and the recycling, and thus demonstrate the systemic effect of agroecology, which leads to improved performance of farming systems when AE practices are combined, as we have already identified in the agro-sylvo-pastoral systems of the same region (Vall et al., 2023).

At ALL-BF level, the setting up of the OnEDA appraoch has made it possible to start achieving some of the objectives pursued by the DIP in terms of milk production, i.e. to increase production in terms of quantity, quality and regularity, and to build the capacity of dairy farmers to master agroecological techniques such as the production, storage and use of fodder, balanced cow rationing, and the recycling of cow dung as manure. The scheme has also helped strengthen DIP's partners. It has helped to animate the life of the DIP over the past three years. As a result, the milk collection centers have registered more affiliated dairy farmers. It has further strengthened the links between the players in the local milk chain (farmers (agro-pastoralists and mini-farms), collectors (independent and collection centers) and processors (local milk and milk powder)).

What has worked particularly well, why and for whom in ALL-BF?

One of the successes has been the strong involvement of stakeholders in all stages of the OnEDA apprach, which is testing agroecological technologies over two years, 2023/24 and 2024/25 (this report only presents the results for 2023/24, as the 2024/25 monitoring is still underway), from the process of setting up the ALL-BF to the evaluation of the agroecological performance of the packages offered to volunteers, via the agroecological package co-design workshops, on-farm experimentation, and participative assessment workshops.

Specifically:

- Experimenting with forage crops on FDPs has been much appreciated by farmers, even though production in the first year was less than stellar, as it enables them to test a new technology on their own farms and choose the forages that suit them best. The same is true of the manure pit experiment, which enables them to use the co-products of the dairy production units to fertilize their crops, particularly forage crops.
- The use of digital advisory tools was also well appreciated by the farmers, even though the prototype versions of the tools used remain largely perfectible. This work shows how important it is to develop high-performance tools in the hands of agricultural advisors, adapted to the individual needs of farmers, to support them in the ''agroecologization'' of their practices and their farms.

What went wrong, why and for whom in ALL-BF?

In 2023/24, biomass production on Fodders Demo-Plots fell short of expectations for a number of reasons, some of which depended on farmers (poor application of technical recommendations provided during co-design/training workshops) and some of which did not (rainfall hazards).

Also, due to a lack of suitable infrastructure for fodder conservation and storage, several farmers were unable to conserve and/or store the fodder produced properly, which had an impact on the setting up of dairy production units.

Volunteer farmers had difficulty obtaining and saving sorghum, cowpea and mucuna seeds. The difficulties mentioned were of several kinds: (i) the difficulty of isolating grain production from the Fodders Demo-Plots from the farm's other crops; (ii) the deterioration of reserved seeds by insects; (iii) the failure to obtain grain due to late sowing, pockets of drought, termite and insect attacks, etc.; and (iv) the consumption of the entire grain production, particularly in the case of cowpea.

As far as manure pits are concerned, some farmers mentioned the difficulty and/or high cost of construction. As an alternative, some preferred to build the pits on high ground.

The application of advice delivered with digital advice tools, as these tools were not completely finalized and the outputs not always perfectly adapted to the knowledge or concrete practices of farmers.

How has the design of innovations (processes, results) contributed to the agroecological transition and the vision of the future of ALL-BF stakeholders?

The process of co-designing experiments with agroecological technologies has made it easier for farmers and ALL-BF stakeholders to understand that the agroecological transition was initially a reflection on the choice of options best suited to the local context in which they will be tested.

On a general level, the agroecological package contributes to the agroecological transition in that :

- The Fodders Demo-Plots have contributed to biodiversity, to the mobilization of a strong collaboration between farmers and to the sharing of knowledge while reducing farm inputs (seeds, forage, concentrates).
- The *CoProdScope* has enabled farmers to better recycle the co-products of their operations.
- The implementation of dairy production units using the *Jabnde* tool has enabled the co-creation of knowledge during the preparation of diets, and the reduction of inputs, particularly concentrates in diets.
- The manure produced in the manure pits has helped improve soil health.

Co-designing and experimenting with agroecological packages has contributed to the realization of ALL's vision with specific regard to dairy farmers:

- Increase milk production and reduce the seasonality of milk production with quality forage, balanced economic diets and improved organic fertilization of cultivated plots.
- Strengthen farmers' technical skills in implementing agroecological packages.

Suggestions and recommendations on how to proceed with code design during the next phase of the Agroecology Initiative

Provide teams with a methodological guide on how to set up a systemic agronomic experiment of agroecological practices with an adapted results evaluation procedure, because in the AEI we were provided with nothing and the evaluation method that was imposed at the end does not seem to us to be adapted to what we set up during the co-design and experimentation. At least in Burkina Faso.

6.2. Reflections, lessons and recommendations on agronomic / agroecological results

Are there certain types of measurements/variables that you consider particularly useful in monitoring and evaluating the testing and design process?

In on-farm experiments, where you have virtually no control over anything, unlike in agronomic trials at a research station, it's vital to monitor and record events and practices from start to finish, so as to be able to explain why things work or don't work.

How do you think the monitoring and evaluation of results carried out by researchers and farmers can best be combined/articulated?

For researchers and farmers to understand each other (better), it may be useful to integrate certain key elements of farmers' local technical knowledge into the monitoring (such as units of measurement, how to describe soils, what they consider to be quality criteria in their production).

6.3. Recommendations and generic or specific plans for the next joint design cycle

Generic recommendation: Propose a methodological guide for the co-design, experimentation and evaluation of agroecological technologies. And not only at the farm scale, but also considering the other links in the value chain from farm to consumption.

Specific for Burkina Faso: For the next design cycle, we plan to write a manual for the co-design, experimentation and systemic and participatory evaluation of agroecological technologies, and to continue producing and developing digital tools for advising farmers on setting up agroecological farming systems (such as *Jabnde*, *CoProdScope*).

Other recommendations

- Support farmers in using the mobile application version of *CoProdScope*
- Co-design with farmers more or less universal diets for different categories of dairy cows
- Set up a weather early warning system

7. Conclusion

This report summarizes the entire process of co-designing, experimenting and assessing agroecological technologies with a large sample of dairy farmers from Burkina Faso's Agroecological Living Landscape using an On-farm Experimental Design for Agroecology (OnEDA). The experimental step of the OnEDA approach consisted of four complementary components: (i) Fodder Demo-Plots; (ii) management of crop and livestock co-products using the CoProdScope tool; (iii) setting up dairy production units using the Jabnde rationing tool; and (iv) setting up efficient covered manure pits.

The Fodder Demo-Plots produced quality forage to feed dairy cows in the dry season. They also produced forage seed that was redistributed between Mother farmers (volunteer farmers in 2023 who planted a Fodder Demo-Plot) and Babie farmers (farmers who received seed from the Mothers) to re-establish the Fodder Demo-Plots during the 2024/2025 crop year. The Fodder Demo-Plots have contributed to biodiversity, mobilized strong collaboration between farmers and shared knowledge, while reducing farm inputs (seed, forage, concentrates).

The CoProdScope tool has enabled a better contribution of crop and livestock co-products from the farm to cover the needs of year N+1 in fodder and manure of the farms that have tested the tool. The fodder produced by the Fodders Demo-Plots was mobilized in the dairy production units for the rationing of lactating cows, and the manure to fertilize the FDP of year N+1.

The Jabnde tool also enabled to co-design balanced and economically acceptable diets with volunteer farmers.

The covered manure pits have produced manure in greater quantity and better quality. Data collection at the level of efficient covered manure pits is ongoing, and analysis of the quality of manure from these pits according to the grazing areas of the animals involved in filling the pits should yield convincing results.

The participatory agronomic assessment of agroecological packages carried out at the level of farmers' cropping systems and dairy cow production units revealed that the introduction of dual-purpose forage crops improved dairy farm production systems. Conventional cropping and cow-feeding practices were mostly ranked below the technologies tested, according to the agroecological dimensions of diversity, synergy, efficiency and recycling. The availability of forage resources made it possible to feed animals during the dry season, which helped reduce the use of feed concentrates. Thus, animals fed on the farm increase the availability of manure, which is then used to improve field fertility.

To perpetuate the momentum generated during the 2023/24 campaign, an Improved On-farm Agroecological Experimental Device (I-OnEDA) based on the lessons learned from the 2023/24 OnEDA was implemented with Mothers and Babies farmers during the 2024/25 campaign. In this new version of the OnEDA, the research questions formulated are: (i) how to improve the OnEDA with new experimenters (Babies farmers); (ii) how certain Babie farmers manage the FDP themselves thanks to the advice provided by the Mother farmers and (iii) do the Mother farmers themselves maintain the practices initiated in 2023/24? In short, we are seeking to see if the practices and know-how put in place during the 2023/24 campaign are mobilized by the farmers themselves to perpetuate the dynamic.

For dairy farmers, we recommend improvements in: (i) the management of fodder demonstration plots (protect fodder plots from livestock intrusion, raise farmers' awareness of the importance of good fodder storage and conservation practices); (ii) the use and management of their co-products to increase fodder storage, manure production and mulch maintenance ; (iii) feeding dairy cows at an affordable cost, using the resources available on the farm (spontaneous rangeland grazing, forage crop residues, cultivated fodder and reasonable use of concentrates available on the market) and (iv) keeping abreast of weather warnings to know the best time to sow.

To the technical services for livestock and meteorology, we recommend: (i) train dairy farmers in forage and forage seed production and conservation; (ii) advise dairy farmers with the CoProdScope tool for intelligent management of their agricultural co-products to optimize forage storage, manure production and mulch maintenance ; (iii) advise dairy farmers with the Jabnde tool for smart management of their dairy cows' feed in order to achieve their goal of affordable milk production; (iv) encourage dairy farmers to expand their forage crop areas (by leasing or acquiring land); (v) set up a weather early warning system to inform dairy farmers.

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