Working Document

WP1:

Loop- and cascade-based co-design of an agroecological dairy farming system in Burkina Faso

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1 Introduction

The growing demand for dairy products in West Africa, together with recent changes in the price of imported milk powder, provides an opportunity to intensify and develop local milk production, collection and processing (Sib *et al.*, 2017; Duteurtre and Vidal, 2018; Vall *et al.* 2021). In Burkina Faso, as throughout West Africa, most of the milk production comes from extensive pastoral and agro-pastoral systems, with semi-intensive and intensive systems also contributing to a lesser extent (Vall *et al.,* 2021). The local dairy value chain has to contend with low cow productivity, the seasonal nature of production - which makes collection difficult - and the relatively low capacity of processing facilities. Faced with this seasonality in production, which is largely due to feed shortages in the dry season, farmers tend to diversify their cow supplementation strategies during that period, with greater storage of crop residues, the use of agro-industrial by-products (AIBPs) and expensive feed concentrates that are beyond the reach of most farmers. In addition to these resources, interest in forage production on farms is beginning to grow. For many years, forage crops were encouraged by research and development, but rarely introduced, as they were less suited to farmers' needs as long as natural grazing was still available to feed livestock (Landais and Lhoste, 1990; Vall *et al*., 2017). In addition, research into forage crops was confined to research stations, with very few applications in the real world where uptake occurs. Today, the situation is changing. The landscape is being reshaped, pastures are increasingly inaccessible, land pressure is increasing, Burkina Faso's inherently poor soil quality is worsened by farming practices that are detrimental to its sustainability, climate uncertainties are growing, with an increase in the frequency of extreme weather events, and transhumance is increasingly impeded. As a result, livestock farmers are looking for ways to adapt and sustainably increase their self-sufficiency in forage and organic 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 offer ways of transforming farming and food systems through a number of principles that could be highly beneficial if implemented in the local dairy value chain. These include seven of the thirteen principles described by 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 dependency on purchased inputs and increasing self-sufficiency); (iii) Soil health (securing and enhancing soil health and performance to improve plant growth, particularly by managing organic matter and enhancing soil biological activity); (iv) Biodiversity (preserving and enhancing species diversity, functional diversity and genetic resources); (v) Synergy (strengthening positive ecological interaction, synergy, integration and complementarity); (vi) Co-creation of knowledge (enhancing co-creation and horizontal sharing of knowledge, including local and scientific innovation, especially through farmer-to-farmer exchange, and (vii) Social values and diets (building food systems based on culture, identity, tradition, social and gender equality of local communities to provide healthy, diversified, seasonal and culturally appropriate diets).

Based on these agroecological principles, diversifying the production of high nutritional value forage, producing quality organic manure, making efficient use of crop and livestock co-products as forage and manure, and applying sound management practices on dairy cow rations on dairy farms appear to be agroecological options that meet producers' expectations for increasing milk production at lower financial cost, with forage being an alternative to traditional dry-season feed resources (cereal straw, spontaneous pastures with low feed value in the dry season, agro-industrial by-products). Better recycling of livestock and crop co-products to produce organic manure will provide significant support for forage production in dairy production units. Lastly, efficient co-product and ration management will help reduce input bills, while improving soil and animal care on the farm.

How can we support this momentum while learning from the past? Farmers very often need certainty *in situ* before adopting an innovative technology recommended by research and development. Their logic, expectations and constraints therefore need to be taken into account and placed at the heart of the design process so that they can be involved in steering the process, thereby making it easier for them to own it. It is in this context that this study, entitled "Loop- and cascade-based co-design of an agroecological dairy farming system in Burkina Faso", is being conducted in Burkina Faso as part of the Agroecological Initiative project.

This report sets out the study methodology, its findings and the momentum generated by the first trial campaign (2023-2024).

2 Materials and methods

2.1 Background to the study

This study took place in Bobo-Dioulasso's dairy production area, which spans the city itself and the surrounding area within a 50 km radius. The participants in this study are members of the Agroecological Living Landscape of Burkina Faso (ALL-BF). The ALL was set up as part of the Agroecology Initiative (‘Initiative sur l'Agroécologie’ or IAE) during a co-design workshop held in March 2023 at CIRDES, based on Bobo Dioulasso's Dairy Innovation Platform (‘Plateforme d'Innovation laitière’ or PIL) and extended to include other stakeholders (support services and external members) (Sib *et al*., 2023). The Bobo-Dioulasso PIL was set up through the Africa-Milk project in 2020. It arose from the desire of local dairy value chain stakeholders in Bobo-Dioulasso and surrounding areas to come together and take action to develop their respective activities. It is made up of dairy farmers, collectors affiliated to milk collection centres, private collectors, dairy processing units, as well as public and private support services. The PIL's overall objective is to increase the daily production of milk up to 18,000 litres through the daily production, collection, processing and marketing of dairy products in Bobo-Dioulasso's dairy production area.

2.2 Approach: Loop- and cascade-based co-design of on-farm experiments

The study used the ALL-BF as the basis for an agroecological package known as the ‘Dispositif Expérimental Agroécologique en Milieu Paysan’ (DEAMP - Experimental Agroecological Farming Scheme). Various co-design workshops were held with ALL-BF stakeholders to present, adjust and endorse the DEAMP, taking into account stakeholders' recommendations, needs and constraints. The DEAMP is based on four (4) complementary components: 1) Implementation of a forage and seed production system, called Fodder Demo-Plot (FDP); 2) Sound management of farm crop and livestock co-products using the *CoProdScope* tool (Zoungrana *et al.*, 2023); 3) Implementation of Dairy Production Units (DPUs) with rations based on FDP forage and designed using the *Jabnde* rationing tool and, 4) Introduction of Efficient Covered Manure Pits (ECMPs) involving the monitoring of livestock and crop co-product recycling from production and the use of organic manure (Figure 1).

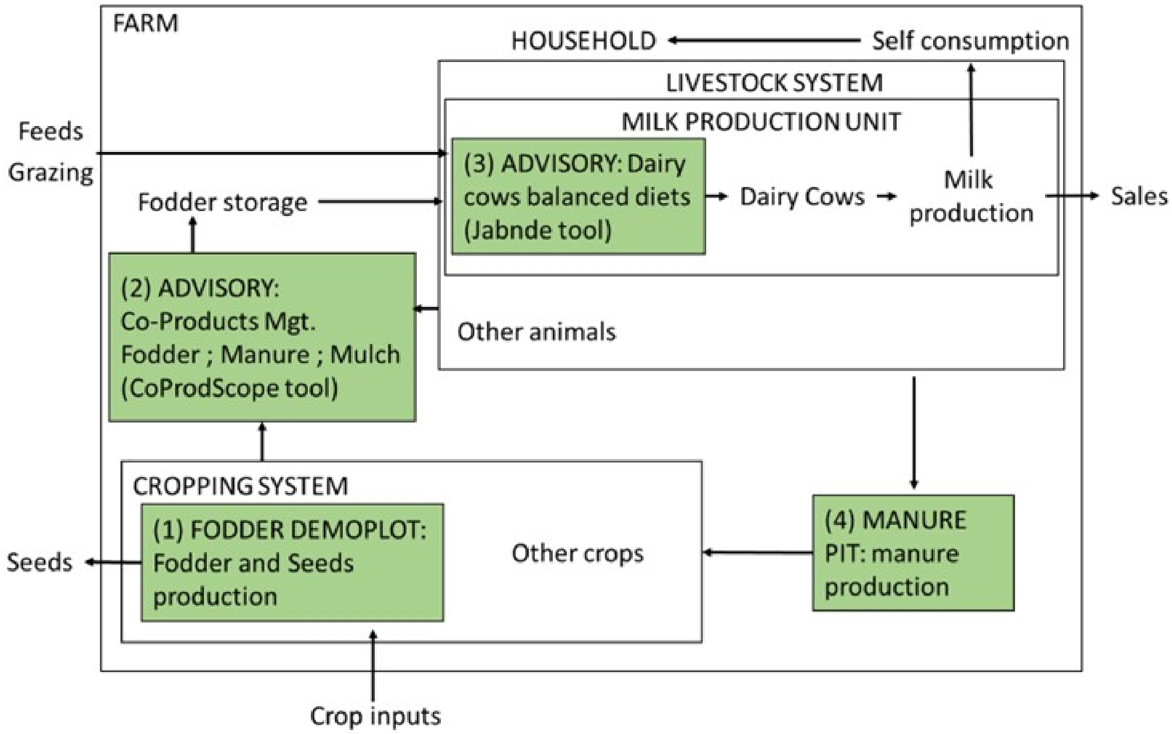


Figure 1. Loop- and cascade-based approach to co-designing a more agroecological dairy farming system

2.2.1 Installation of Fodder Demo-Plots and Efficient Covered Manure Pits

During the Experimental Agroecological Farming Scheme validation workshop, 57 dairy farmers volunteered to set up Fodder Demo-Plots (FDPs). These volunteers came from 9 Milk Collection Centres (MCCs), i.e. an average of 6 volunteers per MCC (Figure 2). The Fodder Demo-Plot (FDP) concept involved planting four crops for forage and seed production on an area of at least 0.5 ha, with at least 0.125 ha for each FDP crop. Crops selected for Fodder Demo-Plots were: (i) Espoir maize and Grinkan sorghum for cereals and (ii) KVX 775-33-2G Tiligré cowpea and *mucuna pruriens var. deeringiana* for legume (Figure 3). This choice was made in consultation with volunteer farmers. Seed quantities made available to farmers were at least 3, 1.5, 2 and 4 kg respectively for maize, sorghum, cowpea and *mucuna*.

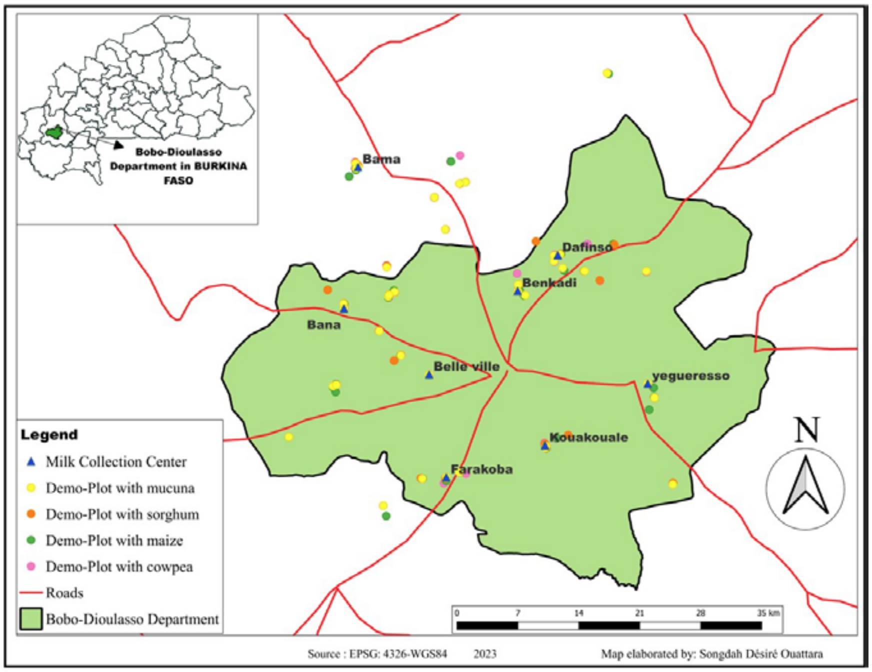


Figure 2. Map of the study area, showing the location of volunteer plots in the area.

Figure 3. Views of the four selected crops for Fodder Demo-Plots

For each crop, 2/3 of the cultivated area was dedicated to forage production and the remaining 1/3 to seed production. Seeds were divided into three equal parts: one part was to be used to replicate 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 neighbours (*Babies*) with a view to introducing the Fodder Demo-Plot on their farms in year N+1 (Figure 4). This principle of seed redistribution was chosen because it would, in theory, enable the practice of forage cultivation to spread rapidly (Theoretical growth in the number of FDPs: No. of FDPs (n) = No. of volunteers in year 1 x $3^{(n-1)}$; with n being the year).

In addition, 15 volunteer agricultural farmers wishing to start forage production were identified in the immediate vicinity of the milk collection centres. These farmers produced fodder which they sold to or traded with dairy farmers as cow feed.

Volunteer farmers were provided with seeds and advice on setting up Fodder Demo-Plots. A follow-up sheet (see appendices) was designed for technical and socio-economic monitoring of forage crops. It records data on technical itinerary, biomass production and yield, seed yields, workload, income and expenditure. This follow-up was carried out in three rounds. Two types of forage yield were determined: potential yield and harvested forage yield. Potential yield was determined using the yield square method. Four 4m^2 yield squares were used on each crop plot prior to grain harvesting. Forage quantities harvested per yield square were averaged and extrapolated to hectare. Harvested forage yield was determined by considering the actual forage harvested by the farmer after the harvest and extrapolated to hectare.

Forage production generated in the Fodder Demo-Plots was preserved and stored for use in formulating efficient dairy rations using the *Jabnde* rationing tool in the dry season.

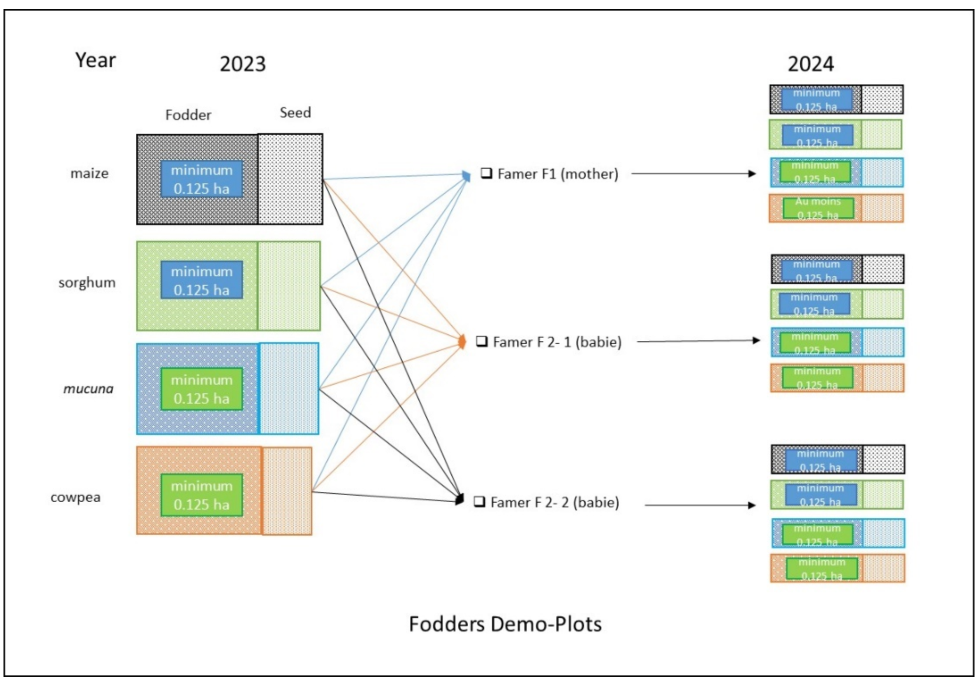


Figure 4. Fodder Demo-Plots experimentation principle

2.2.2 Sound management of farm crop and livestock co-products using the *CoProdScope* tool

2.2.2.1 Introducing the *CoProdScope* (CPS)

The use of the *CoProdScope* (CPS) is based on interaction between an agricultural consultant and an agro-pastoralist. The CPS is a simple tool developed for agro-pastoralists in the savannah areas of West and Central Africa, which is designed to: i) carry out an annual review of Crop Co-Product (CCP) and Livestock Co-Product (LCP) management at farm level for the past year (N), and ii) advise farmers on CCP and LCP management for the coming year (N+1). Ideally, the review should be carried out at the end of year N's dry season, when the co-product recovery cycle is complete. Advice should be given at the end of year N+1's rainy season, when the farmer has a clear idea of the situation regarding year N+1's dry season (crop yields, animal births, availability of spontaneous pasture and water). The review helps reveal the shortfall/surplus between what the farm produces and what it actually needs in terms of forage, manure and mulch. Once the review has been carried out, the CPS can then contribute to the development of a strategy with the farmer in order to generate advice on crop and livestock co-product recovery for year N+1. The *CoProdScope* currently runs on Microsoft Excel. It comprises 12 spreadsheets, several of which are interconnected (Figure 5). In order to provide an accurate picture of the stages involved in the production and use of co-products: (i) the introductory sheets (1.1 and 1.2) describe the workings and organisation of the CPS; (ii) Sheet 2 provides parameters for the input sheet equations; (iii) Sheet 3 is used to collect farm data; (iv) Sheets 4.0, 4.1, 4.2, 4.3 and 4.4 enable the review to be carried out; and (v) Sheets 5.0, 5.1 and 5.2 are used to co-design the advisory process (Zoungrana *et al*., 2023).

2.2.2.2 Use of the *CoProdScope* with volunteer farmers involved in setting up the Experimental Agroecological Farming Scheme

The *CoProdScope* (CPS) tool was used to optimise the management of crop and livestock co-products on 10 farms involved in the implementation of the Experimental Agroecological Farming Scheme. The review of crop and livestock co-product recovery covered the period from June 2022 to May 2023 (year N), and the advisory process ran from June 2023 to May 2024 (year N+1). The review stages were as follows:

Stage 1: collection of general information about the farm, such as the identity of the farmer, the workforce and the equipment (CPS Sheet 3);

Stage 2: Inventory of livestock and livestock co-products (CPS Sheet F4.3);

Stage 3: Crop inventory and estimate of available crop co-products (CPS Sheet 4.2);

Stage 4: Actual annual review of the farm's forage, organic manure and mulch requirements.

Once the review of co-product recovery was completed, a strategy was developed jointly with the farm manager in order to generate advice on how to improve the recovery of crop and livestock co-products for year N+1 using Sheet 5.2. (Figure 6).

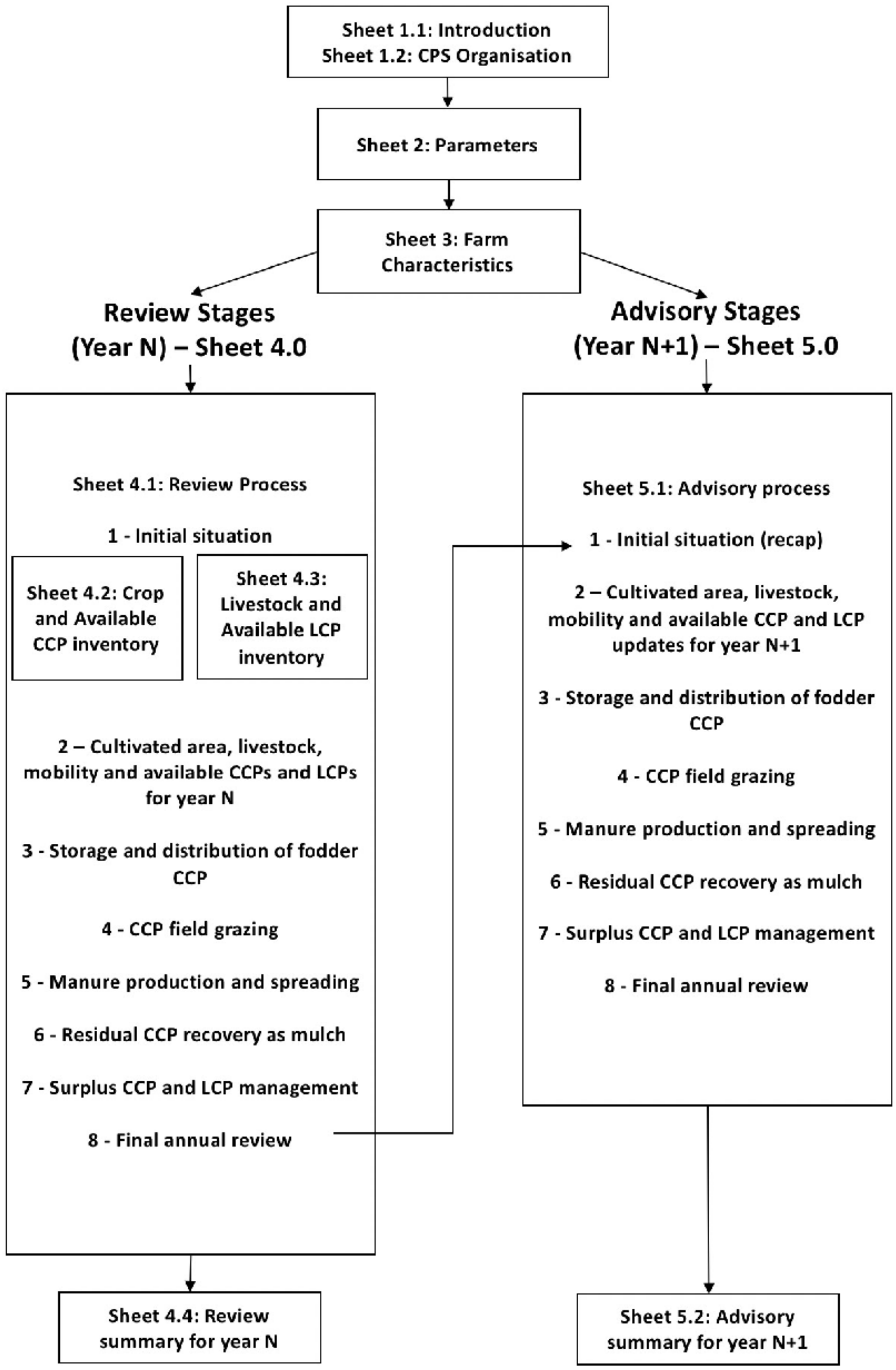


Figure 5. **CoProdScope general structure and stages involved in drawing up farm-level Review and Management Advisory for crop and livestock co-products**

Figure 6. Crop and livestock co-product management advisory sessions on two farms using the CoProdScope

2.2.3 Ration co-design using the *Jabnde* tool and dairy unit monitoring

2.2.3.1 Introducing the *Jabnde* rationing tool

Jabnde is a calculation and rationing tool developed by the CIRAD within the mainstream Microsoft Office/Excel environment and associated with macros and calculation routines programmed in Visual Basic for field use on a basic laptop PC (Lecomte, 2022). The tool has been contextualised to reflect the general characteristics of dairy farming in sub-Saharan Africa, gradually adding nutritional, economic and environmental variables (greenhouse gas (GHG) emissions, nitrogen (N) discharges, etc.). The *Jabnde* tool can be used to prepare individual rations for a herd of up to 29 head of cattle, using the following steps:

Step 1: General description of the site (Sheet 1)

This sheet provides a brief description of the farm and its location, GPS coordinates or Google Maps URL, date of visit and ambient temperature (a useful and important variable in calculating the animal's intake capacity and water requirements).

Step 2: Animal descriptions (Sheet 2)

This sheet describes each animal in the herd that is being considered within a settlement or farm. Data to be entered includes animal name, owner, number of calvings, time on pasture, number of km travelled per day, breed type, sex, age, animal weight, Body Condition Score (BCS), gestation and lactation duration, current and peak milk production. Most parameters are linked to drop-down lists of options. Once this data has been entered, requirements, feed intake capacity and potential milk production values are automatically calculated according to the animal's parameter settings.

Step 3: Choice of feed resources: forage and concentrates (Sheet 3)

This sheet is a table of forage value references as established in the French INRAe system (methodological references) for Milk Forage Units (MFUs) and Intestinal Digestible Proteins (IDPs). It is an integral part of the Jabnde workbook. It was gradually incremented as the tool was used and feedback was received from field users in Senegal, Burkina Faso, Madagascar and Chad. The aim here is to select the feeds to be used for herd rationing.

Step 4: Summary of available forage and feeds (Sheet 4)

This sheet helps sort the selected feeds.

Step 5: Ration preparation: open grazing or ad libitum distribution of basic forage (Sheet 5)

This individual ration calculation sheet is dedicated to situations where the animal either has daily access to pasture, or has free access to a stock of basic forage (straw, hay, etc.) available at will. In the upper part of the sheet, in addition to the buttons for displaying comments/help, a 'Cut & Carry' button can be used to switch to situations where each element of the ration is distributed in a limited quantity. A range of cells entitled 'COST' can be accessed to enter values in local currency units / kg GM (kilogram of gross matter) for each element included in the ration. Further to the right, the price paid to the farmer for each litre of milk delivered to the collector can also be accessed and modified.

The way *Jabnde* works is shown in Figure 7 and can be summarised as follows:

- Knowing the livestock farmer's production target (point 1 on Figure 7);
- Knowing the characteristics of the selected dairy females, such as their genetic type, live weight, pregnancy status, total milk production (point 2);
- Knowing the ingredients making up the ration (pasture, forage, feed; point 3);
- And knowing the purchase price of these ingredients (point 4) and the price of milk paid to the producer (point 5);
- The *Jabnde* tool estimates the amount of spontaneous grazing grass ingested per dairy female put out to pasture;
- The tool can be used to manually adjust the quantities of the other ingredients in the ration (forage and feed), and also offers an automated function for optimising individual supplementation within a least-cost constraint;
- The tool calculates milk production costs and the profit margin on feed costs;
- Finally, *Jabnde* estimates CH_4 and organic manure production levels.

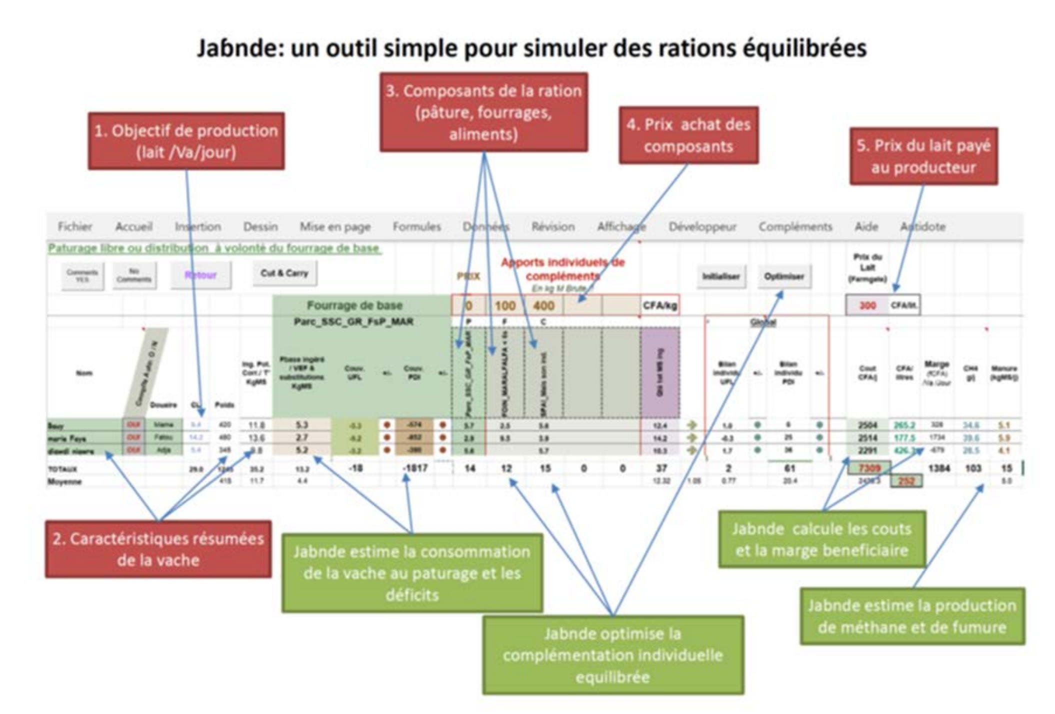


Figure 7. Jabnde operating diagram

2.2.3.2 Setting up dairy units

The experiment was carried out at dairy unit level with a sample of volunteer farmers who had successfully implemented Fodder Demo-Plots (FDPs) and had a large stock of forage. Farmers were selected on a voluntary basis provided that they had: (i) a stock of crop residues produced by the FDP and/or acquired (mucuna hay, cowpea haulms, etc.); (ii) lactating cows and a farm with easy access for monitoring purposes.

Out of an initial pool of 30 volunteer farmers, the experiment was successfully carried out with 20 volunteer farmers. The other ten farmers had only stored cereal crop residues, which tend to reduce the milk production potential of cows on pasture, or had no significant stocks to conduct the experiment. On average, two cows per dairy unit were monitored during the experiment, for a total of 48 rationed cows.

Following the establishment of Fodder Demo-Plots, forage produced was stored for dairy cow rationing in the hot dry season (February, March and April 2024). The *Jabnde* tool was used to provide technical, economic and environmental advice on sound feeding practices for dairy cows in volunteer farmers' dairy production units. The aim was to set up efficient dry-season rations, i.e. balanced and economically acceptable. Dairy units were monitored in four stages:

Stage 1: Collecting reference and input data for *Jabnde*

Prior to the actual experiment, some information was collected on the feeding practices of each dairy unit. The aim was to characterize dairy cows milked in the hot dry season. Data collected between December 2023 and January 2024 related to the number of cows that each volunteer farmer wished to supplement, their genetic type (zebu, taurine or crossbred), their age, weight, pregnancy status (number of months gestation where applicable), the lactation period (i.e. the lactation week for each individual cow), the presence of suckled calves, the production target, milk production at peak lactation, the length of their current lactation, forage stock and available feed.

Stage 2: Simulation-based ration co-design with *Jabnde*

Work began with the simulation and selection of promising rations, taking into account the farmer's milk production target (desired quantity of milk per cow) and available forage. During two or three individual simulation sessions with volunteer farmers, three possible scenarios for integrating Fodder Demo-Plot forage into rations were discussed for each cow. This phase helped to identify promising rations integrating forage from Fodder Demo-Plots, i.e. rations with a balanced energy (MFU) and protein (IDP) content, inexpensive, and with the lowest possible CH_4 emission rate, as provided by the *Jabnde* simulation tool and in line with volunteer farmers' expectations and constraints. Ration adjustments were made and a scenario was agreed in consultation with each voluntary farmer. The selected promising rations were tested in real conditions during stage 3 (Figure 8).

Figure 8. Ration co-design sessions with two volunteer farmers

Stage 3: Experimentation, adaptation and assessment of selected rations

Each volunteer farmer was supported in developing and adapting the promising rations selected during the previous phase, and in measuring the performance results of dairy cows monitored in their dairy unit. The experiment was carried out on part of each volunteer farmer's lactating herd. The average number of cows was two per volunteer farmer and per dairy unit. Numbers and selection of suckler cows were based on forage stocks and production potential. Cows fed promising rations were monitored (Figure 9). The experiment lasted 21 days, including a 14-day adaptation period.

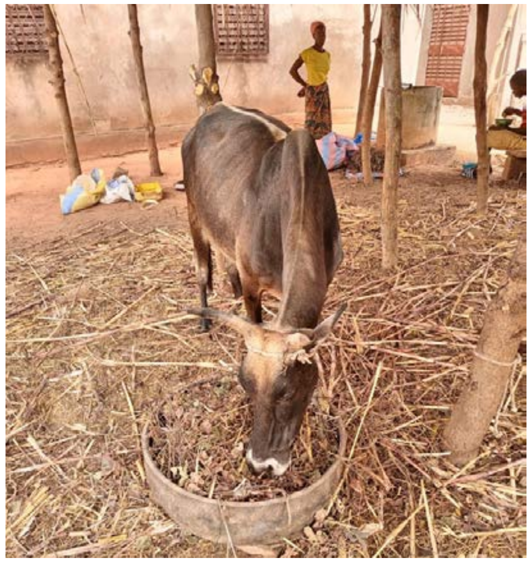


Figure 9. Cow fed mucuna hay as part of its ration

Data collection: During the adaptation period, each volunteer farmer was supported on the first two days of the first two weeks, i.e. on days 1, 2, 8 and 9 of the experiment. They were then left to their own devices. Data collection itself lasted 10 days from day 12. However, only data from the last 7 days was used to analyse the results. The following data was collected using a daily follow-up sheet (see appendix): (i) quantities of feed actually delivered to the cows; (ii) feed intake levels; (iii) daily grazing time; (iv) milked quantities per cow per day, measured using a measuring cup and adding the amount of milk consumed by the calf (approx. one litre/day).

Stage 4: Analysing livestock farmers' perceptions of promising rations

Once the trial phase was over, a perception survey was carried out among the 20 volunteer farmers (see questionnaire in appendix). This survey examined volunteer farmers' perceptions of the impact of implementing these rations on their cows' milk production and their income. Their perception of rationing as a lever for improving cow milk production and income was also assessed.

2.2.4 Installation and monitoring of Efficient Covered Manure Pits

Of the 57 farmers who volunteered to set up Fodder Demo-Plots, 54 offered to build an Efficient Covered Manure Pit. They were provided with cement to this end. Pit volume was planned at 10 m^3, with built-up edges. Once filled, the pits were covered to minimise greenhouse gas (GHG) production, in particular nitrous oxide (NO2). Livestock and crop co-products from the farm were supplied to the pits. Before the compost was emptied from the pit, auger samples were taken at five different points on both 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. Parameters measured included: (i) pH, OM, C, N, P, K content and C/N ratio, and (ii) assessment of the density and diversity of existing weed species. For manure pit monitoring, a follow-up sheet (see appendix) was designed to collect filling data. Data collected related to: (i) pit construction (ii) pit filling and (iii) manure quality assessment and temperature measurements. Monitoring was carried out on a monthly basis from the start of the filling process until manure matures.

2.3 Data collection and analysis

All follow-up sheets were created using the KoBoCollect tool. Statistical analyses were performed using R software, version 4.3.3 (R Core Team, 2024). Analysis of Variance (ANOVA), Kruskal-Wallis and Wilcoxon tests were used for mean comparisons. Validity conditions for each test were checked before they were carried out.

3 Results

3.1 Fodder Demo-Plots setting up and implementation process monitoring

During the 2023/2024 trial campaign, seventy-two (72) volunteer farmers (57 dairy producers and 15 agricultural farmers) were identified for implementing Fodder Demo-Plots. At the end of the experiment, a total of 65 volunteer farmers (54 dairy farmers and 11 agricultural farmers) were found to have implemented at least one Fodder Demo-Plot crop, i.e. a completion rate of 90.28%. The dynamics of Fodder Demo-Plot implementation are shown in figure 10.

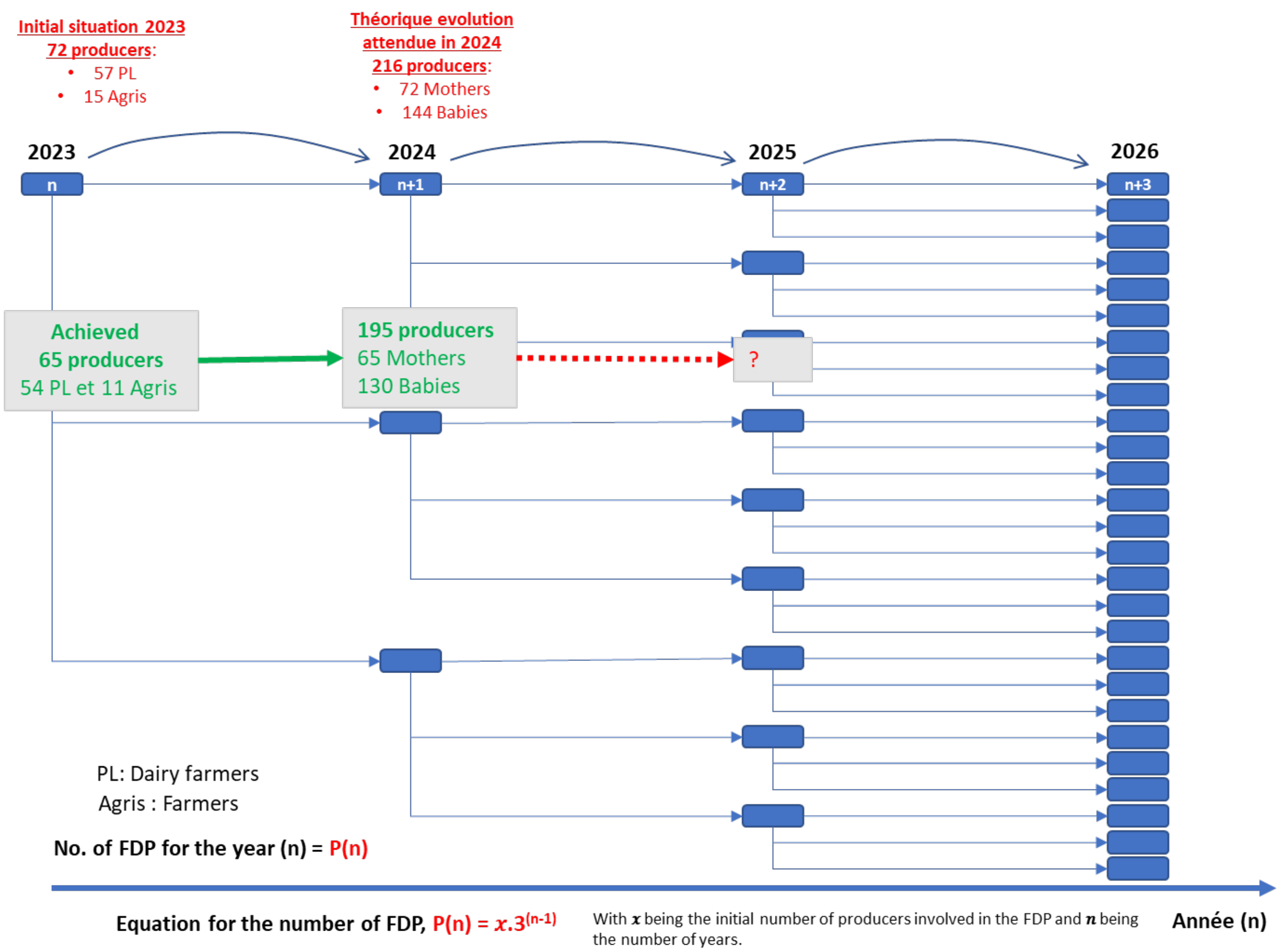


Figure 10. Fodder Demo-Plot development dynamics from 2023 to 2024

3.1.1 Dairy farmers

3.1.1.1 Fodder Demo-Plot surface areas

Fodder Demo-Plots (FDPs) were 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. an excess of 0.04 ha/FDP. The smallest area was 0.38 ± 0.28 ha/FDP and the largest was 2.66 ± 5.32 ha/FDP, both recorded at the Bama and Kouakoualé Milk Collection Centres respectively (Table I). A cooperative of 7 volunteer farmers set up a large 4.85 ha Fodder Demo-Plot at the Kouakoualé MCC.

Table I. Dairy Farmers' Fodder Demo-Plot areas (aggregated by MCC)

Milk Collection Centres (MCCs)	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
Belle ville	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

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

The various crops grown were maize and sorghum for cereals, cowpea and mucuna for legumes. The average maize area recorded was 0.24 ± 0.21 ha/FDP, and sorghum 0.16 ± 0.12 ha/FDP. The average cowpea and mucuna areas recorded were 0.2 ± 0.1 and 0.15 ± 0.15 ha/FDP respectively (Table II and Figure 10). This disparity in acreage is due to farmers' crop preferences.

Table II. **Areas under different crops in Dairy Farmers' Fodder Demo-Plots (aggregated by MCC)**

Milk Collection Centres (MCCs)	Maize area (ha/FDP)	Mucuna area (ha/FDP)	Cowpea area (ha/FDP)	Sorghum area (ha/FDP)
Bama	0.13 ± 0.07	0.08 ± 0.02	0.15 ± 0.15	0.08 ± 0.05
Bana	0.16 ± 0.06	0.09 ± 0.03	0.13 ± 0.06	0.17 ± 0.13
Belle ville	0.17 ± 0.06	0.06 ± 0.04	0.15 ± 0.07	0.13 ± 0.07
Benkadi	0.29 ± 0.19	0.16 ± 0.19	0.26 ± 0.25	0.42 ± 0.44
Dafinso	0.07 ± 0.03	0.13 ± 0.05	0.17 ± 0.1	0.07 ± 0.05
Farakoba	0.27 ± 0.16	0.10 ± 0.05	0.12 ± 0.03	0.09 ± 0.04
Kouakoualé	0.77 ± 0.51	0.54 ± 0.66	0.45 ± 0.51	0.28 ± 0.35
Satiri	0.16 ± 0.04	0.08 ± 0.04	0.15 ± 0.08	0.09 ± 0.02
Yégueresso	0.17 ± 0.11	0.08 ± 0.02	0.22 ± 0.09	0.09 ± 0.02
Total	0.24 ± 0.21	0.15 ± 0.15	0.2 ± 0.1	0.16 ± 0.12

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

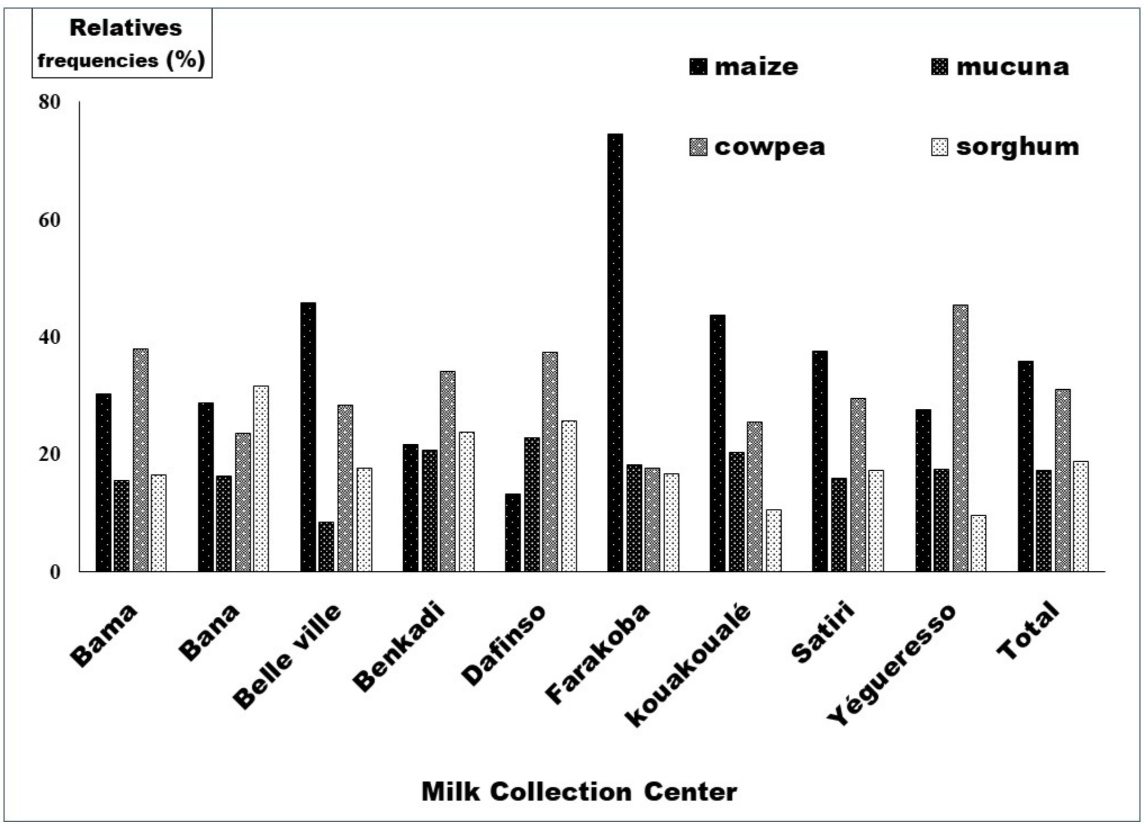


Figure 11. **Proportion of crops in Dairy Farmers' Fodder Demo-Plots (aggregated by MCC)**

3.1.1.2 Grain yields

Maize plots recorded the highest grain yields, followed by sorghum, cowpea and mucuna (Table III). Maize grain yield was 1,079 ± 570 kg/ha/FDP, lower than the potential yield of 6,500 kg/ha stated in the technical data sheet. The highest maize yield was recorded at the Kouakoualé MCC (2,235 ± 1,222 kg/ha/FDP). Sorghum recorded a grain yield of 622 ± 710 kg/ha/FDP, below the potential yield of 2,800 kg/ha shown in the data sheet. The highest sorghum yield was also recorded at the Dafinso MCC (2,330 ± 2,365 kg/ha/FDP). Cowpea grain yield was 214 ± 104 kg/ha/FDP, lower than the average farmer yield of 850 kg/ha shown in the data sheet. The highest cowpea yield was recorded at the Satiri MCC (440 ± 129 kg/ha/FDP). Mucuna recorded a grain yield of 149 ± 131 kg/ha/FDP, below the data sheet's potential yield of between 250 and 2 000 kg/ha. The highest mucuna yield was recorded at the Belle Ville MCC (340 ± 148 kg/ha/FDP). These somewhat lower yields compared to those in the technical data sheets are due to the many constraints faced by farmers in setting up and running the FDPs (Table XI).

Table III. Dairy Farmers' Fodder Demo-Plot grain yields (aggregated by MCC)

Milk Collection Centres (MCCs)	Maize (kg/ha/FDP)	Mucuna (kg/ha/FDP)	Cowpea (kg/ha/FDP)	Sorghum (kg/ha/FDP)
Bama	653 ± 827	322 ± 349	211 ± 232	709 ± 678
Bana	438 ± 322	8 ± 20	97 ± 99	159 ± 230
Belle ville	644 ± 542	340 ± 148	180 ± 103	263 ± 285
Benkadi	957 ± 747	148 ± 349	171 ± 260	307 ± 317
Dafinso	1704 ± 786	242 ± 474	249 ± 129	2330 ± 2365
Farakoba	989 ± 1064	47 ± 75	152 ± 135	302 ± 454
Kouakoualé	2235 ± 1222	185 ± 1	293 ± 39	----
Satiri	864 ± 211	31 ± 40	440 ± 130	503 ± 514
Yégueresso	1228 ± 1238	17 ± 26	132 ± 182	406 ± 487
Total	1079 ± 570	149 ± 131	214 ± 104	622 ± 710

Key: ---- = No data available, sorghum did not germinate at the Kouakoualé MCC; kg/ha/FDP = kilogram per hectare per Fodder Demo-Plot.

The amount of reserved seed was well in excess of the amount of seed received in all MCCs for all FDPs (684% seed reserved). Reserved maize seed was 55.15 ± 31.3 kg/FDP. The highest quantity of reserved maize seed was recorded at the Kouakoualé MCC (112.99 ± 42.44 kg/FDP). Reserved sorghum seed was 31.55 ± 30.83 kg/FDP. The highest quantity of reserved sorghum seed was recorded at the Belle ville MCC (99.67 ± 160.65 kg/FDP). For cowpea, the amount of reserved seed was 13.47 ± 11.54 kg/FDP. The highest quantity of reserved cowpea seed was recorded at the Kouakoualé MCC (41.81 ± 44.9 kg/FDP). Reserved mucuna seed was 18.07 ± 31.61 kg/FDP. The highest quantity of reserved mucuna seed was recorded at the Kouakoualé MCC (100.37 ± 122.56 kg/FDP). Maize recorded the highest quantities of reserved seed per FDP, followed by sorghum, mucuna and cowpea (Table IV).

Table IV. Reserved seed in Dairy Farmers' Fodder Demo-Plots (aggregated by MCC)

Milk Collection Centres	Seed received (kg)	Reserved seed (kg)	Seed reservation rate (%)	Reserved maize seed (kg/FDP)	Reserved mucuna seed (kg/FDP)	Reserved cowpea seed (kg/FDP)	Reserved sorghum seed (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
Belle ville	67	639.11	954	38.35 ± 35.56	22 ± 20.78	11 ± 8.76	99.67 ± 160.65
Benkadi	97.5	707.05	725	100.33 ± 75.95	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 ± 42.44	100.37 ± 122.56	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	4178.04	684	55.15 ± 31.3	18.07 ± 31.61	13.47 ± 11.54	31.55 ± 30.83

Key: ---- = No data available, sorghum did not germinate at the Kouakoualé MCC; kg/FDP = kilogram per Fodder Demo-Plot.

3.1.1.3 Forage yields

Potential yields (assessed using the yield square method) for all crops were higher than forage yields actually harvested (forage actually harvested per hectare). The potential forage yield for maize was 7,244 ± 2,589 kg GM/ha/FDP and its harvested forage yield was 1,439 ± 657 kg GM/ha/FDP. Sorghum recorded a potential forage yield of 11,272 ± 3,498 kg GM/ha/FDP and a harvested forage yield of 2,722 ± 1,266 kg GM/ha/FDP. For cowpea, the potential forage yield was 4,662 ± 2,246 kg GM/ha/FDP, with a harvested forage yield of 1,410 ± 1,201 kg GM/ha/FDP. For mucuna, the potential yield was 8,135 ± 1,690 kg GM/ha/FDP and the harvested forage yield was 2,839 ± 1,611 kg GM/ha/FDP (Table V). Forage actually harvested per hectare was well below potential yields for several reasons: (i) a different yield assessment period; (ii) lack of time on the part of farmers to harvest forage at the right time; (iii) lack of storage equipment; (iv) crop damage by animals... (Table XI).

Table V. Dairy Farmers' Fodder Demo-Plot forage yields (aggregated by MCC)

	Maize		Mucuna		Cowpea		Sorghum	
Milk Collection Centres (MCCs)	Potential forage yield (kg GM/ha/FDP)	Harvested forage yield (kg GM/ha/FDP)	Potential forage yield (kg GM/ha/FDP)	Harvested forage yield (kg GM/ha/FDP)	Potential forage yield (kg GM/ha/FDP)	Harvested forage yield (kg GM/ha/FDP)	Potential forage yield (kg GM/ha/FDP)	Harvested forage yield (kg GM/ha/FDP)
Bama	5421 ± 1121	1712 ± 2311	10310 ± 2440	5300 ± 5045	6837,5 ± 3148	2832 ± 3108	9112 ± 3913	4477 ± 2266
Bana	5457 ± 2480	1115 ± 1050	6570 ± 2781	3882 ± 4848	4350 ± 00	834 ± 969	7375 ± 2831	1523 ± 867
Belle ville	5462 ± 3492	439 ± 729	9300 ± 2150	2160 ± 3110	2875 ± 1096	536 ± 1071	8475 ± 00	1859 ± 2001
Benkadi	5463 ± 3493	1621 ± 1767	9300 ± 2150	1282 ± 1220	2875 ± 1096	680 ± 669	8475 ± 00	901 ± 1173
Dafinso	6711 ± 1974	2200 ± 1593	7745 ± 1224	323 ± 646	7654 ± 7186	2854 ± 4268	16367 ± 2299	3483 ± 2812
Farakoba	8150 ± 1706	2147 ± 2071	5417 ± 2479	2486 ± 4370	4512 ± 2813	2853 ± 4267	10980 ± 7998	3483 ± 2812
Kouakoualé	12133 ± 738	617 ± 1069	7913 ± 2528	----	667 ± 1155	286 ± 648	----	----
Satiri	10837 ± 502	1661 ± 4069	6705 ± 918	4089 ± 2744	5862 ± 515	----	14101 ± 2464	2219 ± 2216
Yégueresso	5562 ± 5780	----	9956 ± 6671	3188 ± 1998	6325 ± 4655	405 ± 494	15287 ± 9492	3834 ± 2800
Total	7244 ± 2589	1439 ± 657	8135 ± 1690	2839 ± 1611	4662 ± 2246	1410 ± 1201	11272 ± 3498	2722 ± 1266

Key: ---- = No data available; kg GM/ha/FDP = kilogram gross matter per hectare per Fodder Demo-Plot; Potential forage yield = forage yield calculated using the yield square method; harvested forage yield = forage yield calculated using the quantity of forage actually harvested by the farmer per hectare.

3.1.2 Agricultural farmers

3.1.2.1 Fodder Demo-Plot surface areas

Agricultural farmers identified to support dairy farmers with dry-season forage resources set up an area 0.99 ± 0.58 ha/FDP larger than the planned area, which was 0.75 ± 0.22 ha/FDP, i.e. an excess of 0.24 ha/FDP. Farmers' total FDP area was 10.57 ha (Table VI).

Table VI. Agricultural farmers' Demo-Plot areas (aggregated by MCC)

Milk Collection Centres (MCCs)	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

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

The average area recorded was 0.36 ± 0.19 ha/FDP for maize and 0.54 ± 0.31 ha/FDP for sorghum. The average cowpea and mucuna areas recorded were 0.49 ± 0.27 and 0.27 ± 0.27 ha/FDP respectively (Table VII).

Table VII. Areas under different crops in Agricultural farmers' Fodder Demo-Plots (aggregated by MCC)

Milk Collection Centres (MCCs)	Maize area (ha/FDP)	Mucuna area (ha/FDP)	Cowpea area (ha/FDP)	Sorghum area (ha/FDP)
Bama	0.39 ± 0.38	0.1 ± 0.00	0.24 ± 0.19	0.25 ± 00
Benkadi	----	----	0.72 ± 00	----
Dafinso	0.53 ± 0.09	0.35 ± 0.2	0.47 ± 0.7	0.51 ± 0.06
Farakoba	----	----	0.85± 00	----
Kouakoualé	----	0.6 ± 00	0.5 ± 0.03	0.86 ± 00
Yégueresso	0.16 ± 0.007	0.01 ± 00	0.15 ± 0.002	----
Total	0.36 ± 0.19	0.27 ± 0.27	0.49 ± 0.27	0.54 ± 0.31

Key: ---- = No data available, these crops were not planted; ha/FDP = hectare per Fodder Demo-Plot.

3.1.2.2 Grain yields

Maize recorded the highest grain yield, followed by sorghum, cowpea and mucuna. Maize grain yield was 1,223 ± 447 kg/ha/FDP, below the potential yield of 6,500 kg/ha specified in the technical data sheet. Sorghum grain yield was 309 ± 370 kg/ha/FDP, below the data sheet's potential yield of 2,800 kg/ha. Cowpea yield was 165 ± 136 kg/ha/FDP, below the average yield of 850 kg/ha shown in the data sheet. Mucuna recorded a grain yield of 145 ± 144 kg/ha/FDP, below the technical data sheet’s potential yield of between 250 and 2,000 kg/ha (Table VIII).

Table VIII. Agricultural farmers' Fodder Demo-Plot grain yields (aggregated by MCC)

Milk Collection Centres (MCCs)	Maize (kg/ha/FDP)	Mucuna (kg/ha/FDP)	Cowpea (kg/ha/FDP)	Sorghum (kg/ha/FDP)
Bama	1738 ± 1819	306 ± 00	168 ± 135	731 ± 00
Benkadi	----	----	434 ± 00	----
Dafinso	951 ± 87	51 ± 73	110 ± 4	154 ± 38
Farakoba	----	----	107 ± 00	----
Kouakoualé	----	0	97 ± 120	41 ± 00
Yégueresso	976 ± 433	224 ± 00	73 ± 104	----
Total	1223 ± 447	145 ± 144	165 ± 136	309 ± 370

Key: ---- = No data available; kg/ha/FDP = Kilogram per hectare per Fodder Demo-Plot.

The amount of reserved seed was well in excess of the amount of seed received in all MCCs (899%). Reserved seed was 110.29 ± 47.81 kg/FDP for maize and 40.16 ± 17.61 kg/FDP for sorghum. For cowpea and mucuna, the amount of reserved seed was 17.69 ± 11.48 and 8.02 ± 1.53 kg/FDP respectively (Table IX).

Table IX. Agricultural farmers' Fodder Demo-Plot seed production (aggregated by MCC)

Milk Collection Centres (MCCs)	Seed received (kg)	Reserved seeds (kg)	Seed reservation rate (%)	Reserved maize seed (kg)	Reserved mucuna seed (kg)	Reserved cowpea seed (kg)	Reserved sorghum seed (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 ± 47.81	8.02 ± 1.53	17.69 ± 11.48	40.16 ± 17.61

Key: ---- = No data available, these crops were not planted; kg = Kilograms

3.1.2.3 Forage yields

Potential yield (assessed using the yield square method) for all crops was higher than harvested forage yield (forage actually harvested per hectare), with the exception of mucuna, where harvested fodder yield was higher than potential yield. This could be due to the heterogeneous nature of mucuna plots. The potential forage yield for maize was 6,756 ± 1,088 kg GM/ha/FDP and its harvested forage yield was 1,135 ± 1,429 kg GM/ha/FDP. Sorghum had a potential forage yield of 8,747 ± 2,053 kg GM/ha/FDP and a harvested forage yield of 2,028 ± 1,095 kg GM/ha/FDP. For cowpea, the potential yield was 4,822 ± 1,531 kg GM/ha/FDP, with a harvested forage yield of 2,184 ± 3,120 kg GM/ha/FDP. For mucuna, the potential yield was 10,608 ± 2,863 kg GM/ha/FDP and the harvested forage yield was 13,217 ± 17,244 kg GM/ha (Table X). Yield differences are due to a number of factors: (i) lack of time on the part of farmers to harvest forage at the right time; (ii) lack of storage equipment; (iii) crop damage by animals... (Table X). Farmers whose main objective was to market fodder, in particular mucuna hay, were able to harvest a maximum amount of this fodder.

Table X. Agricultural farmers' Fodder Demo-Plot forage yields (aggregated by MCC)

	Maize		Mucuna		Cowpea		Sorghum	
Milk Collection Centres (MCCs)	Potential forage yield (kg GM/ha/FDP)	Harvested forage yield (kg GM/ha/FDP)	Potential forage yield (kg GM/ha/FDP)	Harvested forage yield (kg GM/ha/FDP)	Potential forage yield (kg GM/ha/FDP)	Harvested forage yield (kg GM/ha/FDP)	Potential forage yield (kg GM/ha/FDP)	Harvested forage yield (kg GM/ha/FDP)
Bama	5288 ± 3320	3151 ± 4457	13245 ± 00	38304 ± 00	6648 ± 2676	6769 ± 9573	10990 ± 00	3043 ± 00
Benkadi	----	----	----	----	4525 ± 00	275 ± 00	----	----
Dafinso	7093 ± 838	253 ± 358	6628 ± 2394	2315 ± 2403	4855 ± 00	353 ± 500	6960 ± 4723	868 ± 308
Farakoba	----	----	----	----	6300 ± 00	706 ± 00	----	----
Kouakoualé	----	----	----	1000 ± 00	4088 ± 866	309 ± 320	6925 ± 00	2610 ±00
Yégueresso	7888 ± 548	0	11950 ± 00	1474 ± 00	2900 ± 00	86 ± 121	----	----
Total	6756 ± 1088	1135 ± 1429	10608 ± 2863	13217 ± 17244	4822 ± 1531	2184 ± 3120	8747 ± 2053	2028 ± 1095

Key: ---- = No data available; kg GM/ha = kilogram of gross matter per hectare; Potential forage yield = forage yield calculated using the yield square method; harvested forage yield = forage yield calculated using the quantity of forage actually harvested by the farmer per hectare.

3.1.3 Difficulties in setting up Fodder Demo-Plots

The difficulties encountered in setting up the Fodder Demo-Plots, which account for the yields recorded, are summarised in Table XI.

Table XI. Difficulties in setting up Fodder Demo-Plots by MCC

Difficulties encountered	Bama	Bana	Belle ville	Benkadi	Dafinso	Farakob a	Kouako ualé	Satiri	Yéguere sso
Difficulty protecting plots from animals	X	X	X	X	X	X	X	X	X
Pockets of drought; termite and insect attacks	X	X	X	X	X	X	X	X	X
Lack of plots: crops could not be grown	X		X		X				
Forage could not be harvested due to lack of time and manpower		X					X		
Some forage could not be harvested, as grain ripening occurred during a rainy spell			X		X	X			
Late sowing contributed to grain failure, particularly in the case of mucuna and sorghum				X		X	X		
Cowpea and sorghum emergence was problematic on some farms	X			X				X	
One experimenter left his farm for fear of safety					X				
Several experimenters did not set up a Demo-Plot			X						

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

3.2.1 Farm characterisation

The study population consisted of farmers with 49.3 ± 27.6 TLUs/farm at the time of the review (year N), with a maximum of 94 TLUs/farm and a minimum of 9 TLUs/farm. At advisory stage (year N+1), the projected number was 47.2 ± 28.4 TLUs/farm, with a maximum and minimum of 92 and 8 TLUs respectively. Livestock consisted mainly of cattle, sheep and goats. The area farmed per holding was 2.84 ± 1.45 ha, with a maximum and minimum of 6 and 1.25 ha respectively in year N. For year N+1, the projected area was 3.82 ± 2.59 ha, with a maximum and minimum of 10 and 1.5 ha respectively. Herd numbers decreased from year N to year N+1 and cultivated area increased from year N to year N+1. The fall in herd numbers is due to the fact that projected livestock outflows (sales, deaths, losses) exceeded projected livestock inflows (births, purchases). The increase in cultivated area is linked to the introduction of Fodder Demo-Plots. On these farms, family labour was most widely used, with 5 ± 3.8 individuals per farm. Permanent hired labour stood at 1.5 ± 1.18 individuals per farm. Animal-and human-powered equipment (bicycles, dumpers, carts) accounted for most of the equipment used (3.4 ± 2.17 units per farm), compared with engine-powered equipment (pick-ups, tricycles), which is less agroecological, with an average of 1.9 ± 1.52 units per farm. Animal housing and fodder storage equipment consisted mainly of 1.8 ± 0.92 cattle pens and 1.2 ± 1.03 sheds per farm (Table XII). Recycling facilities for livestock co-products (LCP) and crop co-products (CCP) included organic manure collection areas (0.3 ± 0.48 per farm) and manure pits (0.9 ± 1.52 per farm). It should be noted that the introduction of Efficient Covered Manure Pits boosted LCP and CCP recycling capacity.

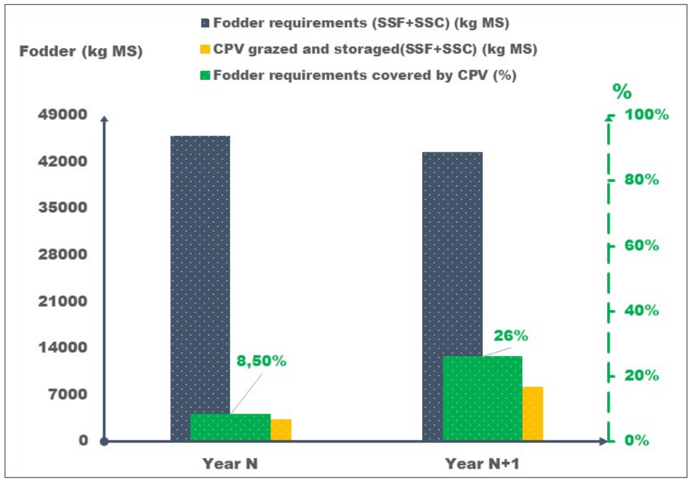
Table XII. Characterisation of farms surveyed with the *CoProdScope* tool

Variables	Conditions	Max	Avg	Min
Labour/farm	Family labour	10	5 ± 3.8	0
	Hired labour	3	1.5 ± 1.18	0
Rolling stock/farm	Agroecological	7	3.4 ± 2.17	1
	Non-agroecological	6	1.9 ± 1.52	1
Fodder storage equipment/farm	Sheds	4	1.2 ± 1.03	0
	Haybarns	2	0.8 ± 0.63	0
Animal housing/farm	Cattle pens	4	1.8 ± 0.92	1
	Barn	1	0.8 ± 0.42	0
LCP and CCP recycling facilities/farm	Organic manure collection areas	1	0.3 ± 0.48	0
	Manure pits	5	0.9 ± 1.52	0

Key: Max = maximum; Avg = average; Min =. minimum; CCP = crop co-products; LCP = livestock co-products; agroecological equipment = animal and human-powered equipment; non-agroecological equipment = engine-powered equipment.

3.2.2 Meeting farms' fodder requirements

Fodder requirements were 45,971 ± 26,816 kg DM/farm for the Cool Dry Season (CDS) and Hot Dry Season (HDS) for year N. These requirements dropped in year N+1 (43,478 ± 28,588 kg DM/farm) as herd numbers decreased. Crop 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 fodder requirements compared with year N. The contribution of crop co-products to fodder requirements rose from 8.5 ± 5.38% to 26 ± 21% respectively from year N to year N+1 (Figure 11).

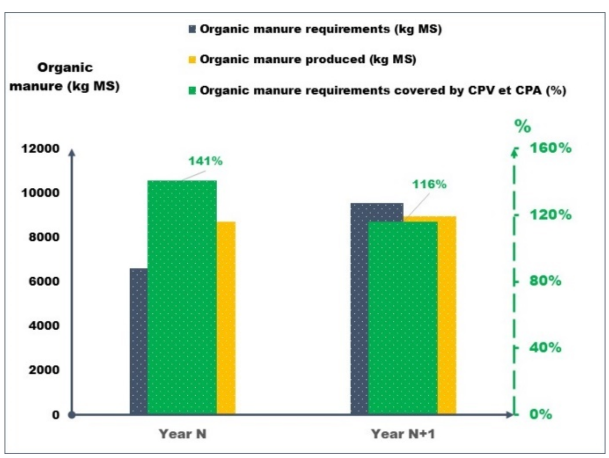


Key: CCP = crop co-products

Figure 12. Contribution of crop co-products to farms' fodder requirements

3.2.3 Meeting farms' organic manure requirements

Organic 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. Production of organic manure rose from 8,690 ± 4,476 kg DM/farm in year N to 8,945 ± 4,835 kg DM/farm following advice in year N+1. The advice helped to reduce the excess organic manure applied to the plots. The contribution of organic manure to farm requirements fell from 141 ± 82% to 116 ± 85% for year N and year N+1 advice respectively (Figure 12). Organic manure production more than covered farm needs. This is due to the large number of TLUs and the small size of the farms.

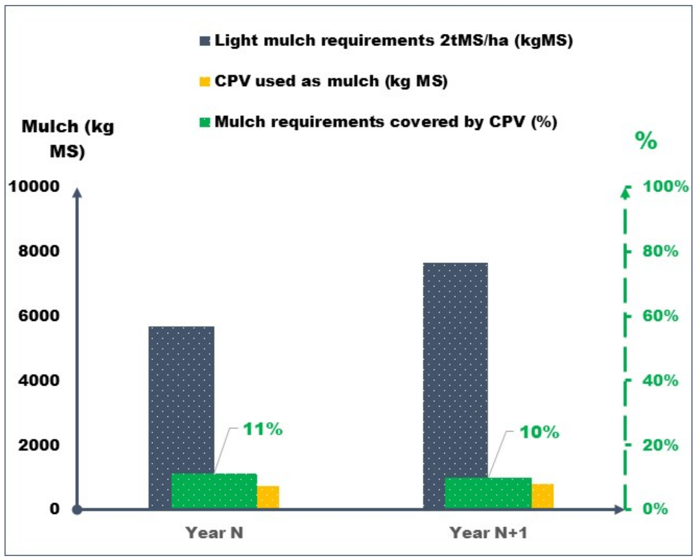


Key: CCP = crop co-products; LCP= livestock co-products; OM = organic manure.

Figure 13. Contribution of organic manure to meeting farm requirements

3.2.4 Meeting farms' mulch requirements

Mulch requirements (light: 2tDM/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. Crop co-products used as mulch amounted to 725 ± 1,385 kg DM/farm in year N and 791 ± 1152 kg DM/farm in year N+1. Advice failed to improve the coverage of mulch requirements in year N+1. That coverage fell from 11 ± 17% to 10 ± 12% in years N and N+1 respectively (Figure 13).



Key: CCP = crop co-products

Figure 14. Contribution of crop co-products to meeting farm requirements

3.3 Dairy production unit monitoring and ration co-design using *Jabnde*

3.3.1 Characterisation of dairy cows

Categorising rationed cows according to breed and feeding regime led to three groups of animals being identified: Group 1, with 32 zebu cows grazed on pasture (ZCP); Group 2, with 5 zebu cows kept in stalls (ZST); and Group 3, with 11 mixed cows grazed on pasture (MCP) (Figure 14).

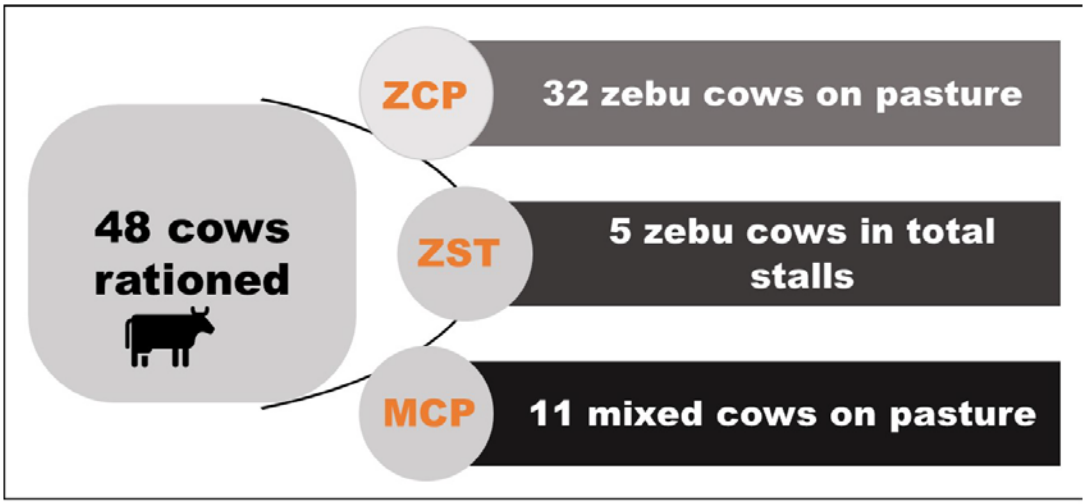


Figure 15. Categories of rationed cows

Zebu cows grazed on pasture (ZCP) and Zebu cows kept in stalls (ZST) were older (p < 0.5) than mixed cows grazed on pasture (MCP). ZCPs and ZSTs were 6.62 ± 1.99 and 6.6 ± 1.67 years old/cow respectively. MCPs were 4.86 ± 1.7 years old/cow. In addition, mixed cows grazed on pasture had a higher live weight than zebu cows on pasture and zebu cows kept in stalls (p < 0.001). MCPs had a live weight of 436 ± 83.2 kg/cow, while ZCPs and ZSTs had live weights of 242 ± 26.5 and 285 ± 92.9 kg/cow respectively. Parity, Body Condition Score (BCS) and lactation length were identical (P>0.05) for all three groups of cows. Cows' overall appearance was good with an average BCS of 3.77 ± 0.41, 3.39 ± 0.42 and 3.4 ± 0.42 per cow for MCPs, ZCPs and ZSTs respectively. Milk Forage Unit (MFU), Intestinal Digestible Protein (IDP) and Dry Matter (DM) requirements were higher (p < 0.001) in MCPs than in ZCPs and ZSTs. MFU and IDP requirements for MCPs were 11.8 ± 2.77 MFU/cow and 902 ± 205 IDP/cow respectively. MFU requirements for ZCPs and ZSTs were 5.26 ± 0.54 and 4.8 ± 1.09 MFU/cow respectively, while IDP requirements were 336 ± 36.4 and 353 ± 63.2 IDP/cow (Table XIII).

Table XIII. Characterisation of rationed cows

Cow characterisation and needs	MCP	ZCP	ZST	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 length (weeks)	16.8 ± 13	20.3 ± 9.88	13.6 ±7.27	> 0.05
MFU requirements	11.8 ± 2.77 a	5.26 ± 0.54 b	4.8 ± 1.09 b	< 0.001
IDP requirements	902 ± 205 a	336 ± 36.4 b	353 ± 63.2 b	< 0.001
Potential DM requirements	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

Key: MCP = mixed cows on pasture; ZCP = zebu cows on pasture; ZST = zebu cows in stalls; different letters on the same line indicate a significant difference.

3.3.2 Co-design of cow feeding regimes

No significant difference (P> 0.05) was found between planned, distributed and ingested feed quantities for all rationed cows, although distributed quantities were slightly higher than planned.

Co-designed rations for mixed cows grazed on pasture consisted of 5.14 ± 2.28 kg GM/d/cow of forage and 10.7 ± 4.08 kg GM/d/cow of concentrates. Quantities actually distributed were 6.62 ± 3.59 and 11.1 ± 3.65 kg GM/d/cow for forage and concentrates respectively. The proportion of forage distributed in the ration (37.4%) was lower than that of concentrates (62%). Grazing areas were mainly fields (100%), with an actual duration of 2.24 ± 0.43 H/d/cow vs. a planned duration of 4.78 ± 0.44 H/d/cow (Table XIV).

For zebu cows grazed on pasture, co-designed rations consisted of 2.12 ± 1.06 kg GM/d/cow of forage and 2.56 ± 0.66 kg GM/d/cow of concentrates. Quantities actually distributed were 2.73 ± 2.11 and 2.49 ± 0.79 kg GM/d/cow for forage and concentrates respectively. The proportion of forage distributed in the ration (52.3%) was higher than that of concentrates (47.7%). Grazing areas were composed of fields (75%) and lowlands (25%), with a grazing duration of 7.7 ± 2.55 H/d/cow vs. a planned duration of 7.5 ± 2.5 H/d/cow (Table XIV).

For zebu cows kept in stalls, co-designed rations consisted of 7.6 ± 1.19 kg GM/d/cow of forage and 1.6 ± 1.5 kg GM/d/cow of concentrates. Quantities actually distributed were 7.84 ± 2.38 and 1.61 ± 1.52 kg GM/d/cow for forage and concentrates respectively (Table XIV). The proportion of forage distributed in the ration (82.96%) was much higher than that of concentrates (17.04%).

Table XIV. Characterisation of co-designed rations

Cow rationing		Forage (kg GM/d/cow)	Concentrates (kg GM/d/cow)	Total feed (kg GM/d/cow)
MCP	Planned quantities	5.14 ± 2.28 a	10.7 ± 4.08 a	15.9 ± 4.46 a
	Quantities distributed	6.62 ±3.59 a	11.1 ± 3.65 a	17.7 ± 2.43 a
	Intake quantities	5.81 ± 3.66 a	11.1 ± 3.65 a	16.9 ± 2.70 a
	P-value	> 0.05	> 0.05	> 0.05
ZCP	Planned quantities	2.12 ± 1.06 a	2.56 ± 0.66 a	4.69 ± 0.73
	Quantities distributed	2.73 ± 2.11 a	2.49 ± 0.79 a	5.22 ± 2.09
	Intake quantities	2.02 ± 1.14 a	2.40 ± 087 a	4.42 ± 1.01
	P-value	> 0.05	> 0.05	> 0.05
ZST	Planned quantities	7.6 ± 1.19 a	1.6 ± 1.5 a	9.2 ± 1.82 a
	Quantities distributed	7.84 ± 2.38 a	1.61 ± 1.52 a	9.45 ± 2.53 a
	Intake quantities	6.07 ± 2.27 a	1.61 ± 0.51 a	7.68 ± 2.51 a
	P-value	> 0.05	> 0.05	> 0.05

Key: MCP = mixed cows on pasture; ZCP = zebu cows on pasture; ZST = zebu cows in stalls; kg GM/d/cow = kilogram of gross matter per day per cow; identical letters in a column for a group of cows indicate that there are no significant differences (p > 0.05).

In general, for co-designed rations, coverage of Milk Forage Unit (MFU) requirements was lower than coverage of Intestinal Digestible Protein (IDP) requirements. In the co-designed rations, the coverage of MFU and IDP requirements of mixed cows on pasture was significantly different (p < 0.001) from that of zebu cows on pasture and zebu cows in stalls (Table XV).

Co-designed rations did not fully cover the MFU requirements of the MCPs (- 0.64 ± 0.59 MFU/cow). However, their IDP requirements were largely covered (280 ± 104 IDP/cow). For ZCPs and ZSTs, the co-designed rations covered MFU and IDP requirements, with respectively 0.009 ± 0.22 and 0.36 ± 0.53 MFU/cow for MFUs, and 193 ± 91 and 162 ± 72 IDP/cow for IDPs.

In the review, potential organic manure production was found to be 5.76 ± 1.01 kg DM/d/cow for MCPs, higher (< 0.001) than for ZCPs and ZSTs, which were 3.64 ± 0.35 and 3.79 ± 0.82 kg DM/d/cow respectively. Potential methane (CH_4) production in MCPs (36.91 ± 7.29 g/d/cow) was higher ($P<0.001$) than for ZCPs (20.1 ± 2.21 g/d/cow). It should be noted that the *Jabnde* tool does not calculate potential CH_4 production for animals kept in stalls, hence the lack of data for ZSTs.

Table XV. Review of co-designed rations

Review of co-designed rations	MCP	ZCP	ZST	P-value
Coverage of needs (MFU/cow)	- 0.64 ± 0.59 a	0.009 ± 0.22 b	0.36 ± 0.53 c	< 0.001
Coverage of needs (IDP/cow)	280 ± 104 a	193 ± 91 b	162 ± 72 b	> 0.5
Ingestion (kg DM/cow)	15.1 ± 3.22 a	7.65 ± 1.43 b	8.02 ± 1.77 b	< 0.001
Organic manure (kg DM/d/cow)	5.76 ± 1.01 a	3.64 ± 0.35 b	3.79 ± 0.82 b	< 0.001
CH4 production (g/D/cow)	36.91 ± 7.29 a	20.1 ± 2.21 b	----	< 0.001

Key: ---- = No data available (*Jabnde* does not calculate potential CH4 production for animals kept in stalls); MCP = mixed cows on pasture; ZCP = zebu cows on pasture; ZST = zebu cows in stalls; MFU = milk forage unit; IDP = intestinal digestible protein; kg DM/d/cow = kilogram of dry matter per day per cow; g/d/cow = gram per day per cow; different letters on the same line indicate a significant difference ($p < 0.001$).

3.3.3 Milk production of rationed cows

Milk production from mixed cows on pasture (MCPs) was 10.7 ± 2 L/d/cow. This was significantly higher than for zebu cows on pasture (ZCPs) and zebu cows in stalls (ZSTs), which produced 1.05 ± 0.52 and 1.55 ± 0.55 L/d/cow respectively. However, no significant difference ($P> 0.05$) was found between the average weight of a litre of milk for all cows. Average milk weights were 1.06 ± 0.08; 1.16 ± 0.16 and 1.14 ± 0.06 kg/L/cow respectively for MCPs, ZCPs and ZSTs.

For mixed cows grazed on pasture, the actual milk production (10.7 ± 2 L/d/cow) was identical ($P> 0.5$) to the desired production, which was 10.5 ± 4.28 L/d/cow (Figure 15). The actual feed cost to produce a litre of milk was 127 ± 40.6 FCFA/L/cow. This cost was identical ($P> 0.05$) to the expected cost of 123 ± 34.2 FCFA/L/cow.

For zebu cows grazed on pasture, the actual milk production (1.05 ± 0.52 L/d/cow) was lower ($P < 0.001$) than the desired production of 1.77 ± 0.7 L/d/cow (Figure 15). The actual feed cost per litre of milk was 391 ± 171 FCFA/L/cow. This cost was higher ($P < 0.001$) than the expected cost of 208 ± 66.4 FCFA/L/cow.

For zebu cows kept in stalls, the actual milk production (1.55 ± 0.55 L/d/cow) was identical ($P> 0.05$) to the desired production, which was 1.7 ± 0.45 L/d/cow (Figure 15). The actual feed cost to produce a litre of milk was 135 ± 112 FCFA/L/cow. This cost was identical ($P> 0.05$) to the expected cost of 113 ± 88.3 FCFA/L/cow.

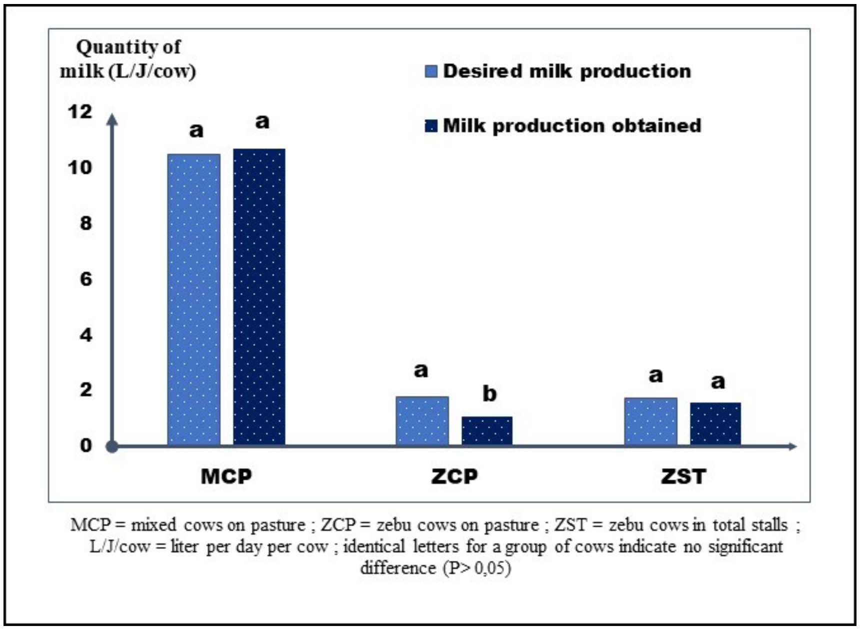


Figure 16. Average milk production of rationed cows

3.3.4 Analysing volunteer farmers' perceptions of rations co-designed with *Jabnde*

3.3.4.1 Livestock farmers' perception of milk production per cow

For all rationed cows, volunteer farmers reported that the production target had been fully achieved for 27.1% of cows. However, significant differences were found between zebu cows on pasture (ZCPs), those kept in stalls (ZSTs) and mixed cows on pasture (MCPs). For ZCPs and ZSTs, the milk production target was fully achieved for 9.40% and 40% of cows respectively (Figure 16 and Figure 17). For MCPs, the production target was fully met for 72.7% of cows (Figure 18). Reasons for achieving milk production targets were linked to: (i) the balanced ration co-designed with the *Jabnde* tool; (ii) the provision of quality fodder; and (iii) the provision of feed concentrates. As for the reasons for failing to achieve production targets, they were linked to: (i) poor forage quality; (ii) poor cow health; (iii) cows' lactation stage (end of lactation); (iv) feed rejection for some feed; (v) other reasons (weakened cow at start of experiment, distant watering source, calving rank).

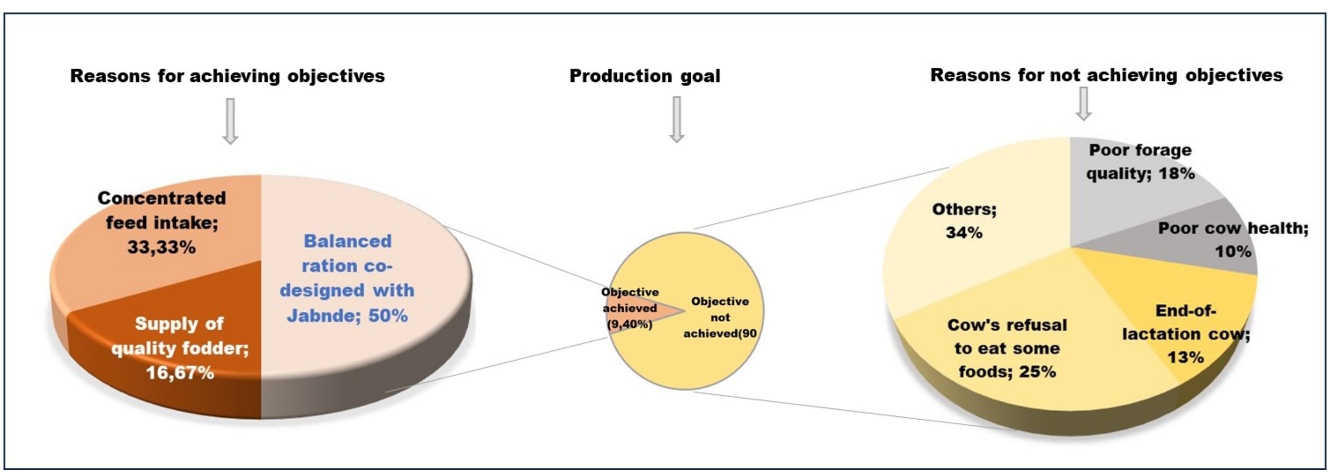


Figure 17. Reasons for achieving or failing to achieve milk production target for ZCPs

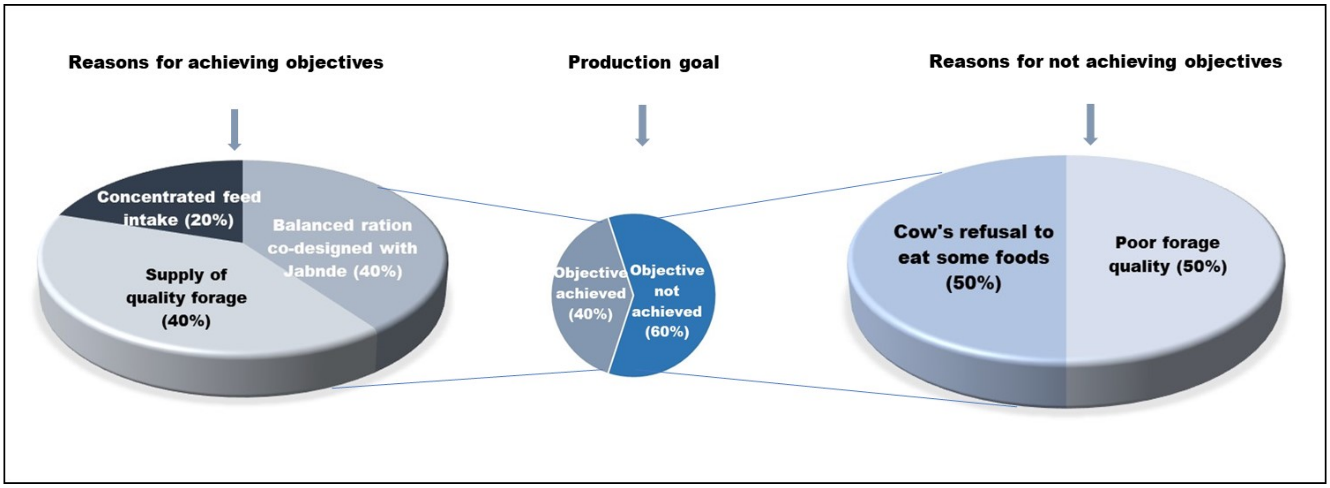


Figure 18. Reasons for achieving or failing to achieve milk production target for ZSTs

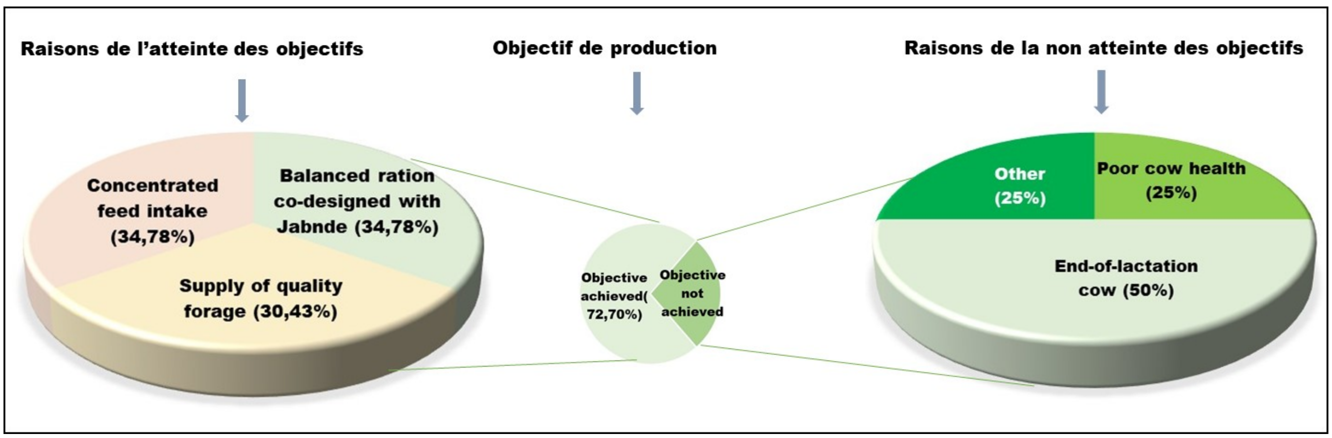
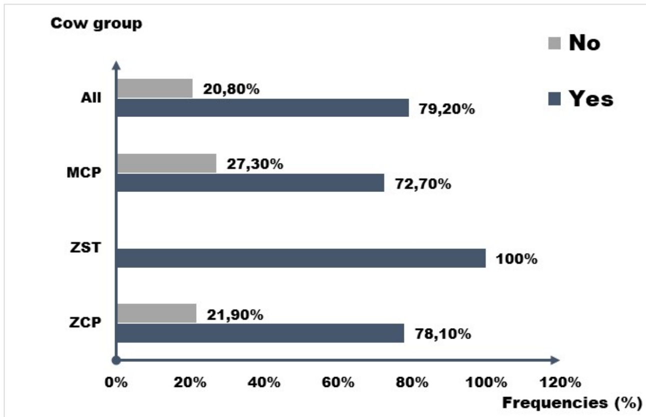


Figure 19. Reasons for achieving or failing to achieve milk production targets for MCPs

Although only 27.1% of cows achieved the desired milk production, volunteer farmers stated that they were partially satisfied with the level of production achieved by 79.20% of cows (Figure 19). They felt that milk production was ultimately fairly close to that desired for 100, 73 and 69% of cows respectively for ZSTs, MCPs and ZCPs. Furthermore, volunteer farmers stated that they would not have reached the quantity of milk produced without the rationing programme implemented on all cows (100%) with the *Jabnde* tool.



MCP = mixed cows on pasture ; ZCP = zebu cows on pasture ; ZST = zebu cows in total stalls

Figure 20. Volunteer farmers' satisfaction levels with actual milk production figures

For zebu cows grazed on pasture, volunteer farmers felt that milk production had increased slightly during the experiment for 65.63% of the cows, that it had increased significantly for 25% of the cows and that it had remained constant for 9.38% of the cows compared with milk production at the start of the experiment (Figure 20). Reasons given for milk production remaining constant during the experiment included: (i) poor cow health, (ii) reduced forage biomass on pasture and (iii) poor milking practices.

For zebu cows kept in stalls (ZSTs), volunteer farmers felt that milk production had increased significantly during the experiment for all cows (100%) compared with milk production at the start of the experiment. This is due to the fact that ZSTs were no longer expending energy accessing pasture, as they were being fed sufficient quantities of feed in the stalls.

For mixed cows grazed on pasture, volunteer farmers felt that milk production had increased slightly during the experiment for 54.55% of the cows, that it had increased significantly for 27.27% of the cows and that it had remained constant or decreased slightly for 9.1% of the cows compared with milk production at the start of the experiment (Figure 20). Reasons given for milk production remaining constant or declining were the occurrence of mastitis for stable milk production and the gestation effect for declining milk production.

In terms of gross profit margin, taking into account ration costs, volunteer farmers stated that they were satisfied with 100 %, 72.7 % and 62.5 % of cows respectively for ZSTs, MCPs and ZCPs.

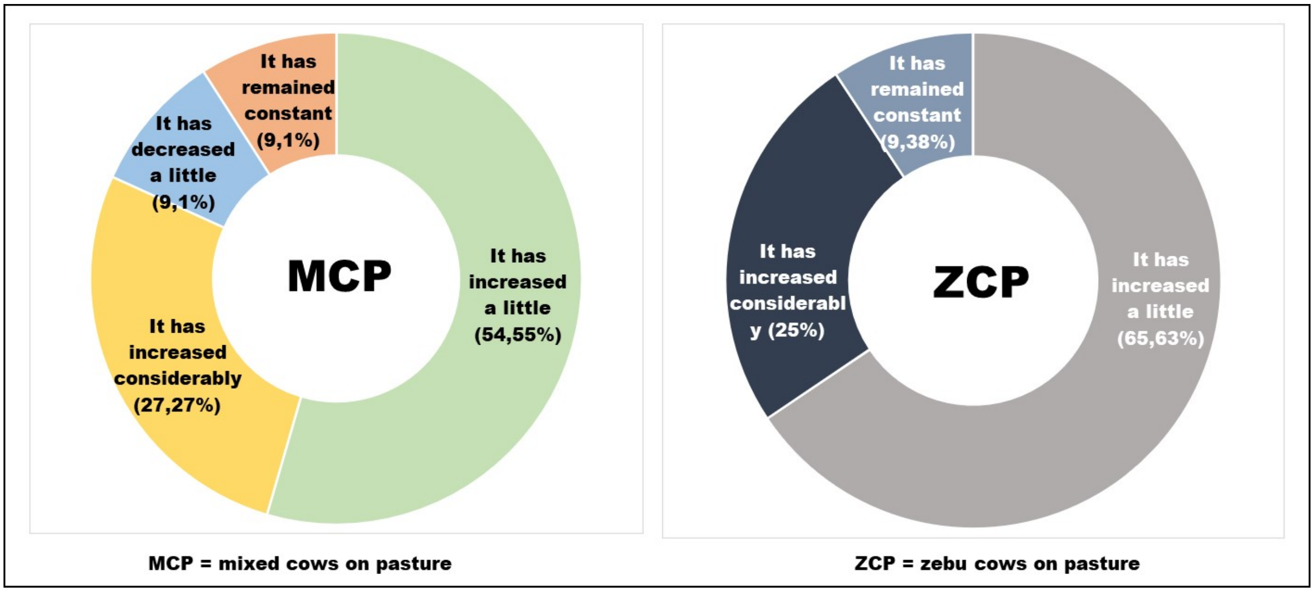


Figure 21. Volunteer farmers' perception of changes in milk production during the experiment compared with milk production at the start of the ZCP and MCP experiment

3.3.4.2 Volunteer farmers' perception of the use of *Jabnde* as a lever for improving cow milk production and income

Volunteer farmers all felt that *Jabnde* was a good tool for improving cow milk production and income (Figure 21).

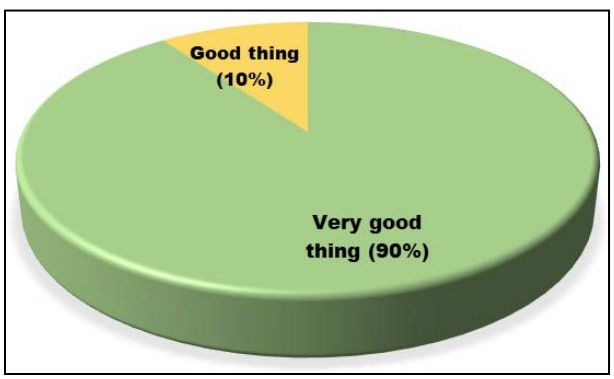


Figure 22. Volunteer farmers' perception of the use of *Jabnde* as a lever for improving cow milk production and income

The majority of volunteer farmers (90%) stated that milk quantities from rationed cows were greater than those from cows that had not been rationed using the *Jabnde* tool. They also felt that rationing with *Jabnde* had raised their awareness on several levels (Table XVI).

Table XVI. Impacts of cow rationing with Jabnde at dairy unit level

Variables	Conditions	Frequency (%)	Reasons
Impact of the experiment on volunteer farmers	Awareness of feed quantities to be distributed	100	---
	Awareness of feed type required for good production	80	---
	Awareness of expenses incurred	50	---
	Awareness of the need for proper fodder storage	45	---
	Other (importance of forage crops; importance of cow rationing; animal stalling)	30	---
Milk production differences between rationed and non-rationed cows	The quantity of milk produced by rationed cows is greater than that of non-rationed cows using the Jabnde tool	90	Thanks to the ration co-designed with Jabnde
	The quantity of milk produced by rationed cows is lower than that of non-rationed cows using the Jabnde tool	5	Selected cow was less productive
	Milk quantities from cows rationed and not rationed with the Jabnde tool are similar	5	End-of-lactation cow

Key: ---- = No data available

3.3.4.3 Volunteer farmers' perception of the effect on workload of using forage from Fodder Demo-Plots in cow rationing

All volunteer farmers felt that using Fodder Demo-Plots (FDP) in rationing had significantly reduced their use of concentrates. However, 65% of volunteer farmers felt that using FDPs had increased their workload, particularly in harvesting (69.23%) and production (46.15%). The increase was significant for 61.54% of volunteer farmers who felt that using ADTs had increased their workload (Table XVII).

Table XVII. Impact on workload of using FDPs in cow rationing

Variables	Conditions	Frequency (%)
Impact on workload of using FDPs	Yes	65
	No	35
Affected functions	Production	46.15
	Storage	30.77
	Harvest	69.23
Level of workload increase	Very high	15.38
	Significant	61.54
	Low	23.08

Key: FDP: Fodder Demo-Plot

3.4 Efficient Covered Manure Pits setting up and implementation process monitoring

Among the 54 farmers who volunteered to build and use a covered manure pit, the following numbers were recorded as of 30 April 2024:

- 19 pits (35.19% of initial estimate) built, filled and covered;
- 26 pits (48.15% of initial estimate) currently being filled ;
- 1 pit (1.85% of initial estimate) under construction ;
- 1 pit (1.85% of initial estimate) abandoned and
- 7 pits (12.96% of initial estimate) not built.

In the following sections, results are presented only for the 19 pits that were built, filled and covered.

3.4.1 Characterisation of Efficient Covered Manure Pits

The Efficient Covered Manure Pits (ECMPs) were built on gravel (73.68%), sand (21.05%) and clay (5.26%) soils. The majority of them were set up in fields (47.36%). The other pits were either on-farm pits (26.32%) or both on-farm and field pits (26.32%), where houses stood on the edge of fields. ECMPs were located 41.05 ± 58.76 m from the barn and 166.11 ± 252.99 m from a water source. Their volume was 12.86 ± 4.20 m/pit and their sizes are shown in Table XVIII.

Table XVIII. Dimensions of Efficient Covered Manure Pits

Pit dimensions	Medium/pit
Length (m)	3.14 ± 0.47
Width (m)	3.10 ± 0.43
Depth (m)	1.28 ± 0.20
Volume (m3)	12.86 ± 4.20

Key: m = metre; m3 = cubic metre

3.4.2 Set-up costs for Efficient Covered Manure Pits

ECMPs edges were stabilised using brick (66.67%) and stone (33.33%) construction. The number of rows was 2.41 ± 0.87 rows/pit, with a height of 35.47 ± 22.19 cm/pit. Digging and stabilising individual ECMPs required the involvement of 5.11 ± 1.94 people for 6 ± 3.25 days, for a duration of 8.84 ± 2.97 hours/day. Total expenditure for the construction of individual pits was 33,247.37 ± 19,138.56 FCFA (Figure 22).

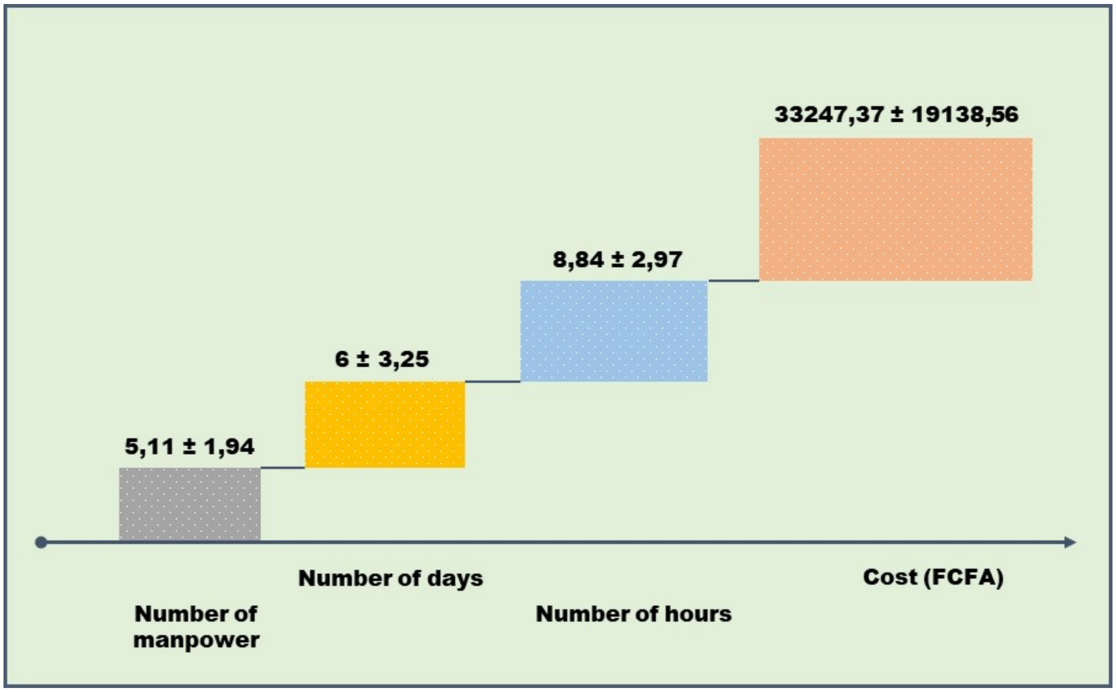


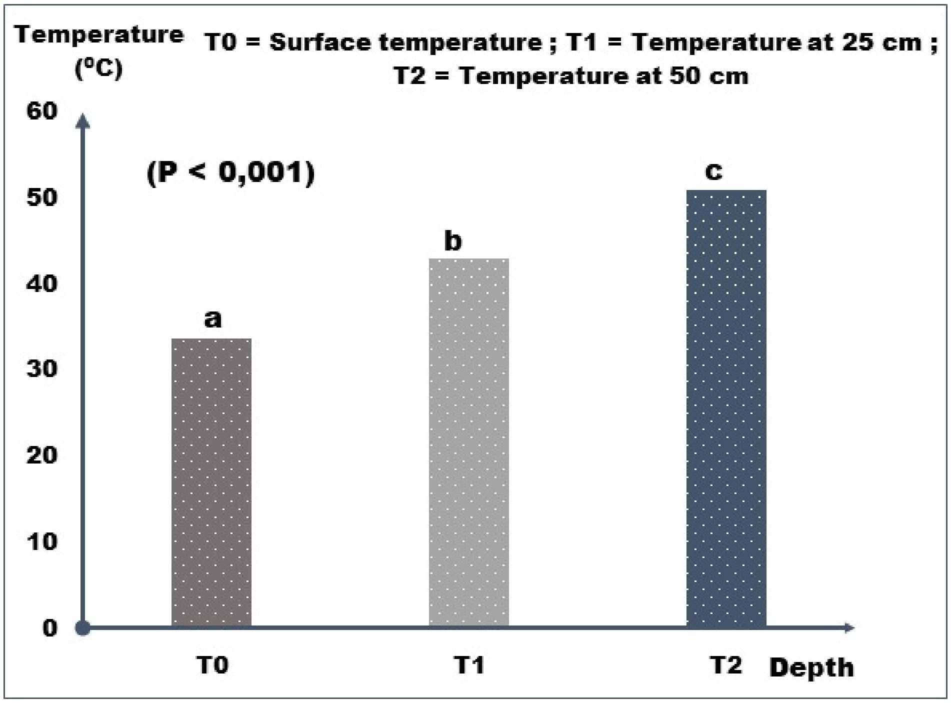
Figure 23. Costs associated with the setting up of an Efficient Covered Manure Pit

3.4.3 Filling of Efficient Covered Manure Pits

The Efficient Covered Manure Pits (ECMPs) were filled on an ongoing basis depending on the availability of crop co-products (CCP) and livestock co-products (LCP). The quantity of livestock co-products used (2,823 ± 1,845.64 kg LCP/pit) was higher ($P < 0.001$) than that of crop co-products (469.2 ± 313.15 kg CCP/pit). This high level of LCPs is due to the fact that volunteer farmers prioritised the use of CCPs to feed livestock. The animals whose co-products were used to fill the pits included 12.79 ± 13.7 dairy cows, 12.89 ± 17.23 other cattle and 14.64 ± 14.69 small ruminants. CCPs used included refused fodder and litter, coarse CCPs (straw) and household waste. The quantity of water added to accelerate co-product breakdown inside the pits was 2,822.99 ± 1,845.64 L/pit. Filling time was 102.37 ± 58.96 days/pit. Visual assessment of the breakdown of the initial CCP and LCP mixture was 50 ± 18.63% upon closure, with the presence of biological activity.

3.4.4 Manure pit temperature variation

After filling, the pits were covered with tarpaulins. Temperature measurements at three different levels revealed an increase in temperature from top to bottom. Surface temperature was 33.6 ± 5.49^{0}C/pit, while those measured at 25 and 50 cm were 42.9 ± 8.79 and 51 ± 8.03^{0}C/pit respectively (Figure 23).



Different letters for temperatures at different depths indicate a significant difference (P < 0.001).

Figure 24. Average temperature variation in covered manure pits in relation to depth below surface

4 Conclusion

During this first trial campaign (2023/2024), the 'Dispositif Expérimental Agroécologique en Milieu Paysan' (DEAMP - Experimental Agroecological Farming Scheme) was introduced to 65 volunteer farmers (54 dairy farmers and 11 agricultural farmers). Fodder Demo-Plots enabled dairy farmers to produce and store 1,439 ± 657; 2,722 ± 1,266; 1,410 ± 1,201 and 2,839 ± 1,611 kg GM/ha/FDP of forage for maize, sorghum, cowpea and *mucuna* respectively. Reserved seed amounted to 55.15 ± 31.3; 31.55 ± 30.83; 13.47 ± 11.54 and 18.07 ± 31.61 kg/FDP respectively for maize, sorghum, cowpea and *mucuna*. Agricultural farmers produced and stored more legume fodder (cowpea and *mucuna)* than dairy farmers. Agricultural farmers produced and stored 1,135 ± 1,429; 2,028 ± 1,095; 2,184 ± 3,120; 13,217 ± 17,244 kg GM/ha/FDP of forage for maize, sorghum, cowpea and *mucuna* respectively. Reserved seed amounted to 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.* Fodder produced by agricultural farmers was sold to or traded with dairy farmers as cow feed.

The *CoProdScope* tool improved the contribution of grazed and stored crop co-products to meeting fodder requirements for the 10 farms surveyed in year N+1. The contribution of crop co-products to meeting fodder requirements rose from 8.5 ± 5.38% to 26 ± 21% respectively from year N to year N+1 following advice. These farms generally produce large quantities of organic manure (8,690 ± 4,476 kg DM/farm in year N), far in excess of the farm's needs (6,616 ± 3,267 kg DM/farm in year N). This is due to the large number of TLUs (49.3 ± 27.6 TLUs/farm in year N) and the small size of the farms (2.84 ± 1.45 ha/farm in year N).

Forage produced by FDPs was used in dairy units for the rationing of lactating cows. The *Jabnde* tool helped co-design balanced, economically acceptable rations for 20 volunteer producers with 48 lactating cows. The quantity of milk produced was 1.05 ± 0.52, 1.55 ± 0.55 and 10.7 ± 2 L/d/cow respectively for zebu cows grazed on pasture, zebu cows kept in stalls and mixed cows grazed on pasture. Despite the fact that only 27.1% of cows achieved the desired milk production, volunteer farmers expressed partial satisfaction with the level of milk production achieved by 79.20% of cows. They felt that milk production was ultimately fairly close to that desired. The reasons for failing to achieve milk production targets were linked to: (i) poor forage quality; (ii) poor cow health; (iii) cow at the end of lactation; (iv) feed rejection for some feed; (v) other reasons (weakened cow at the start of the experiment, distant watering source, calving rank).

As of 30 April 2024, 19 Efficient Covered Manure Pits (35.19% of the initial estimate) had been built, filled and covered, with a capacity of 12.86 ± 4.20 m^3. Digging and stabilising individual pits required the involvement of 5.11 ± 1.94 people for 6 ± 3.25 days, for a duration of 8.84 ± 2.97 hours/day. Total expenditure for the construction of individual pits was 33,247.37 ± 19,138.56 FCFA.

Protection of plots from animals, pockets of drought and crop pest attacks were the main difficulties encountered at Fodder Demo-Plot level. The lack of farm records was the main constraint during the CoProdScope survey, as farmers had to put a lot of thought into providing data for the review process. In terms of cow rationing, the isolation of rationed cows from the rest of the herd while receiving their daily rations was the main difficulty.

To sustain the momentum generated by this first trial campaign, volunteer farmers still need support. Consequently, during the second trial campaign (2024/2025), an **Improved** Experimental Agroecological Farming Scheme ('Dispositif Expérimental Agroécologique en Milieu Paysan Amélioré', DEAMPA) based on lessons learned from the 2023 DEAMP will be implemented with Mothers (volunteer farmers from 2023 who established an FDP) and Babies (farmers who received seed from Mothers). Research questions are: (i) how can the DEAMP be improved; (ii) how do Babies manage the FDP themselves and (iii) do Mothers maintain practices on their own?

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6 Appendices

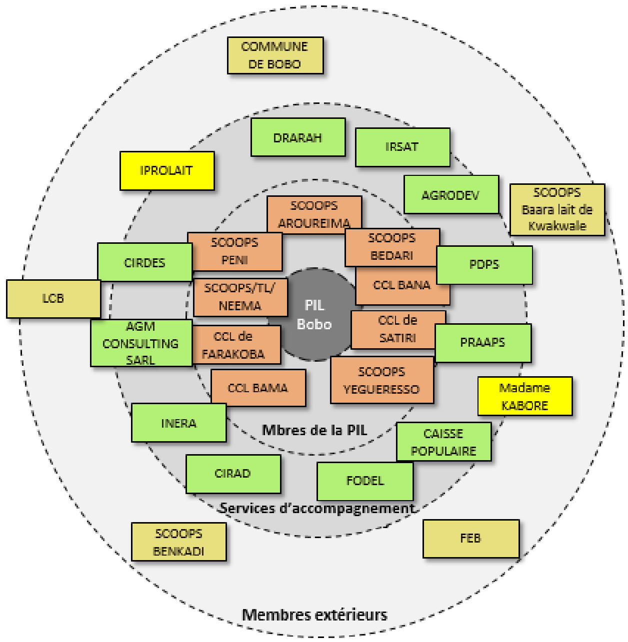

Figure 25. PIL stakeholder positioning

Figure 26. Efficient Covered Manure Pits

Figure 27. Fodder from a Fodder Demo-Plot

6.1 Forage crop follow-up sheet (FDP)

Farmer Details

Farmer code: //______________//

Type of farmer (1-Dairy farmer; 2- Agricultural farmer): //______________//

Name: //______________//

First name(s): //______________//

Village / MCC (1- Satiri; 2- Dafinso; 3- Kouakoualé; 4- Bana; 5- Bama; 6- Farakoba; 7- Belle ville; 8- Benkadi; 9- Yégueresso): //______________//
Forage crop (1- Maize; 2- Sorghum; 3-Niebe; 4-Mucuna): //______________//
Area: //______________ha//
Plot's geographical coordinates: //______________//

How far is the plot from the house: _________ km

Technical itinerary monitoring

Tasks	Practice methods
Soil type	Local name: //_______________// Gravel ☐ Sandy ☐ Clay ☐
Previous 2022	Fallow land: Yes☐ No ☐ If not, Crop: //__________________// Organic manure: Yes☐ No ☐
Did you apply organic manure?	Yes☐ No ☐ If yes, when? : //________________// Type of OM used: 1= Raw manure (animal dung +/- litter); 2 = Compost /____/ OM burial method: 1 = none; 2 = ploughing; 3 = other, to be specified /_______/ Quantity (carts, tricycles, trailers, other: specify): //_____________// No. of family labour: //____________// No. of days for family labour: //____________// No. hours/day for family labour: //____________// Hired labour: Yes☐ No ☐ If yes No. of hired labour: //____________// No. of days for hired labour: //____________// No. hours/day for hired labour: //____________// Expenses (Fcfa): //____________//
How did you prepare the soil?	Pre-cleaning: Yes☐ No ☐ Type of ploughing: 1 = no-till; 2 = manual ploughing (daba); 3 = ploughing in TA with ridges; 4 = ploughing in TA with planks; 5 = tractor ploughing /____/ Date: //_________//

	No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you apply a total herbicide?	Yes□ No □ If so, which one? : //___________// Quantity: //___________// (specify unit) Date: //____________// No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you apply a selective herbicide?	Yes□ No □ If so, which one? : //_______// Quantity: //________// (specify unit) Date: //______// No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________//

	Expenses (Fcfa): //___________//
How did you sow?	Date: //_____________// Sowing technique: 1 = Manual; 2 = Seeder /____/ Sowing geometry: 1 = in-line with wedge; 2 = in-line with rope; 3 = in-line on ridges; 4 = staggered /____/ Seed dose (kg): //_______// No. of grains per bunch: //_______// Line spacing (cm): //____________// Dibbling spacing (cm): //___________// Emergence rate: 1 = 0%; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100% /____/ No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes☐ No ☐ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you reseed?	Yes☐ No ☐ Date: //_____________// Seed dose (kg): //_______// No. of grains per hole: //______________// No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes☐ No ☐ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//

Was singling used?	Yes□ No □ Date: //______// Number of plants left after: /____/ No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you apply NPK?	Yes□ No □ If yes, when? : //_________// Quantity: //____________// (specify unit) Application method: 1 = burial; 2 = surface spreading /____/ No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you apply urea?	Yes□ No □ If yes, when? : //_____________// Quantity: //_____________// (specify unit) Application method: 1 = burial; 2 = surface spreading /____/ No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □

	If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you apply a 2nd dose of urea?	Yes□ No □ If yes, when? : //_____________// Quantity: //_____________// (specify unit) Application method: 1 = burial; 2 = surface spreading /____/ No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you weed?	Yes□ No □ If so, when? :_____________ Weeding technique: 1 = Manual; 2 = Weeder/Manga hoe /____ / 3= Other (specify) No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you do a 2nd weeding?	Yes□ No □ If so, when? :_____________ With which tool? //_________// (specify) No. of family labour: //___________//

	No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you weed by hand?	Yes□ No □ If yes, when? : //__________// No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you carry out hilling?	Yes□ No □ If yes, when? : //_______________// To bury urea Yes□ No □ No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Did you apply an insecticide treatment?	First treatment date: //________// Product: //______________// Application rate (quantity) /_______/

	Reason for application: 1 = following the technical itinerary; 2 = because of pest attack /____/ Describe the pest being controlled, if applicable /_______________/ Physiological stage of plants: 1= Emergence; 2 = Tilling; 3= Bolting/Branching; 4 = Flowering; 5 = Fructification /_____/ No. of family labour: //____________// No. of days for family labour: //____________// No. hours/day for family labour: //____________// Hired labour: Yes☐ No ☐ If yes No. of hired labour: //____________// No. of days for hired labour: //____________// No. hours/day for hired labour: //____________// Expenses (Fcfa): //____________//
Did you carry out a 2nd insecticide treatment?	Second treatment date: //_________// Product: //_______________// Application rate (quantity) /________/ Reason for application: 1 = following the technical itinerary; 2 = because of pest attack /____/ Describe the pest being controlled, if applicable /_______________/ Physiological stage of plants: 1= Emergence; 2 = Tilling; 3= Bolting/Branching; 4 = Flowering; 5 = Fructification /_____/ No. of family labour: //____________// No. of days for family labour: //____________// No. hours/day for family labour: //____________// Hired labour: Yes☐ No ☐ If yes No. of hired labour: //____________// No. of days for hired labour: //____________// No. hours/day for hired labour: //____________// Expenses (Fcfa): //____________//
Grain harvesting	Date://_________// Quantity of grain harvested (kg): //____________// Quantity of seed harvested (kg): //____________// No. of family labour: //____________//

	No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Forage harvesting	Date://________// Cutting stage: 1 = Bolting/Branching; 2 = Flowering; 3 = Fructification; 4 = Ripening /____/ Quantity of forage harvested: //______________// (specify unit: kg, bales, carts, etc.) Drying mode: 1= Only in the sun; 2 = Curing in the sun, then drying in the shade; 3 = In the shade only /___/ No. of family labour: //___________// No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Storage	Storage conditions Packaging • Bales • Bulk • Other: //_________// Storage equipment: 1 = in a heap on a shed; 2 = in a heap under a shed; 3 = in the open; 4 = on a tree; 5 = in a sheltered area or hay barn /___/ Estimated stock: //_______// (specify unit: kg, bales, other...) Estimation of forage quality (at harvest time) : • Very good

	• Good • Average • Poor • Very poor

Vegetation monitoring

Dates	Conditions
First follow-up date	General appearance: //____// Vegetation stage: 1= Emergence; 2 = Tilling; 3= Bolting/Branching; 4 = Flowering; 5 = Fructification //___________// Other comments: //___________________________//
Second follow-up date	General appearance: //_________________________________// Vegetation stage: 1= Emergence; 2 = Tilling; 3= Bolting/Branching; 4 = Flowering; 5 = Fructification //___________// Other comments: //__________________//
Third follow-up date	General appearance: //______________________// Vegetation stage: 1= Emergence; 2 = Tilling; 3= Bolting/Branching; 4 = Flowering; 5 = Fructification //___________// Other comments: //______________//
At harvest time	General appearance: //_______________ ______________________________// Vegetation stage: //_____________________________// Other comments: //__________________________//

Measuring forage biomass production

Plots	Conditions
Plot 1	Fresh weight (kg): //__________// Dry weight (kg): //__________// Plot area (m²): //________//
Plot 2	Fresh weight (kg): //__________// Dry weight (kg): //__________// Plot area (m²): //________//
Plot 3	Fresh weight (kg): //__________// Dry weight (kg): //__________// Plot area (m²): //________//
Plot 4	Fresh weight (kg): //__________// Dry weight (kg): //__________// Plot area (m²): //________//

6.2 Daily data collection form for co-designed dairy units

I. Farmer and observing agent details

Farmer's surname and first name(s): /____/
Farmer code: /_________________________________/ ; Village:
/____/
MCC: /____/
Observing agent's surname and first name(s):/____/

II. Collection period

Experiment start date: /_____________________________________/
Today's date: /___________________________________/ ; Day of the experiment:
/__________________________________/

III. Feed ration distributed per cow

Animals grazed: 1 = Yes, 2 = No /_________/

If yes, please specify departure and return times and indicate the type of pasture used the previous day (D - 1):

- Daytime grazing
  - Start time: /_________________________________/
  - Return time/_________________________________/
  - Grazing area (1=hills; 2=lowlands; 3=full; 4=fields; 5=transient pastures on hardpans): /_____________________________/

- Night grazing
  - Start time: /_________________________________/
  - Return time: /_________________________________/
  - Grazing area (1=hills; 2= lowlands; 3=full; 4=fields; 5=transient pastures on hardpans): /_____________________________/

Quantities (kg) of each ingredient distributed by the farmer the day before (D - 1) :

Designations		**C 1:**	**C 2:**	**C 3:**	**C4:**	**C5 :**	**C6 :**	**C7 :**
Ingr. 1:	**Qt dist.:**							
Cost :	**Qt refu.:**							
Ingr. 2:	**Qt dist.:**							
Cost:	**Qt refu.:**							

Ingr. 3: **Cost:**	**Qt dist.:**							
	Qt refu.:							
Ingr. 4: **Cost:**	**Qt dist.:**							
	Qt refu.:							

NB: C = Cow;* Ingr. *= Ingredient; Qt dist. = Quantity distributed; Qt refu. = Quantity refused.

Milk production per cow

For each cow, please provide details of quantities milked the previous evening and this morning

Cows:							
Quantities milked last night :							
Quantities milked this morning :							

Comments (brief description of the barn, feed and water troughs, and any observations on cow and experimenter behaviour)

/____
____
____
____
____
____
____
____
____
____/

6.3 Perception analysis of livestock farmers who set up a dairy unit - Questionnaire

Perception analysis of livestock farmers who set up a dairy unit - Questionnaire

This survey examines livestock farmers' perceptions of the impact of implementing co-designed rations on their cows' milk production and their income. Their perception of rationing as a lever for improving cow milk production and income will also be assessed.

1. Farmer code: //________________//
2. Surname and first name(s): //________________//
3. Village: //________________//
4. MCC: //________________//

5. Usually, what were your main sources of feed for your cows in the dry season? 1=Natural grazing; 2=Distribution of coarse fodder; 3=Distribution of quality fodder; 4=Distribution of concentrates; 5=Other (specify): //________________//

5.1. List them in order of importance: //________________//

6. During the experiment, what were your main sources of feed for your cows? 1=Natural grazing; 2=Distribution of coarse fodder; 3=Distribution of quality fodder; 4=Distribution of concentrates; 5=Other (specify): //________________//

6.1. List them in order of importance: //________________//

7. What was your production goal? 1=To reduce production costs; 2=To increase milk production; 3=To increase milk production and reduce production costs; 4=Other (please specify): //________________//

8. Milk production trend per cow

8.1. During the experiment, monitoring showed that your XX cow produced an average of X l/day.

8.1.1. Is this quantity close to what you hoped to achieve? 1=Yes; 2=No: //________________//

8.1.2. Are you satisfied with your cow X's milk production? 1=Yes; 2=No: //________________//

8.1.3. If not, why not: //________________//

8.2. How did you perceive the production trend of cow XX during the experiment? 1=It increased a lot; 2=It increased a little; 3=It remained constant; 4=It decreased a little; 5=It decreased a lot: //___________________//

8.2.1. Please explain why: //___________________//

8.3. Has your production target been reached? 1=Yes; 2=No: //________________//

8.3.1. If yes, what are the reasons? 1=Balanced ration co-designed with *Jabnde*; 2=Provision of quality forage; 3=Provision of feed concentrates; 4=Other (specify): //________________//

8.3.2. If not, what are the reasons? 1=Poor forage quality; 2=Cow XX in poor health; 3=Cow XX at end of lactation (dry period); 4=Cow XX refuses some feed; 5=Other (specify) //_______________//

8.4. Without the ration recommended by the *Jabnde* tool, would you have achieved this level of milk production? 1=yes ; 2=no: //__________________//

8.5. Your gross profit margin from milk sales after factoring in the cost of feed was XX FCFA/d with the experimental ration for cow XX.

8.5.1. Is this gross profit margin close to what you would have liked to achieve? 1=Yes; 2=No: //_______________//

8.5.2. Are you satisfied with this profit margin? 1=Yes; 2=No: //_______________//
8.5.3. If not, why not: //_______________//

9. How do you compare milk production from rationed and non-rationed cows using the *Jabnde* tool? 1=Milked quantities from rationed cows are higher than those from non-rationed cows using the *Jabnde* tool; 2=Milked quantities from rationed and non-rationed cows using the *Jabnde* tool are similar; 3=Milked quantities from rationed cows are lower than those from non-rationed cows using the *Jabnde* tool: //_______________//

9.1. Please explain why: //_______________//

10. Before the experiment, how many litres of milk a day did you deliver to the MCC? //_______________//
11. During the experiment, how many litres of milk a day did you deliver to the MCC? //_______________//

12. Has the use of fodder from the Fodder Demo-Plot enabled you to reduce the use of concentrates in your rationing system? 1=Yes ; 2=No: //_______________//

13. Does the use of fodder in your rationing system have an effect on labour? 1=Yes; 2=No: //_______________//

13.1. If yes, has it increased or decreased workload? 1=Increased ; 2=Decreased //_______________//

13.2. Please specify which work positions are affected 1=Production; 2=Storage 3=Distribution; 4=Harvesting; 5=Other (please specify): //_______________//

13.3. If workload increase, please specify: 1=Negligible; 2=Small; 3=Significant; 4=Very significant: //_______________//

13.4. If workload decrease, please specify: 1=Negligible; 2=Small; 3=Significant; 4=Very significant: //_______________//

14. What do you think of *Jabnde*'s advice on cow rationing as a way of improving milk production and income? 1=Very good 2=Good 3=Neither good nor bad 4=Bad 5=Very bad //________________//

15. What did this experiment bring you? 1=Awareness of expenses incurred; 2= Awareness of feed quantities to be distributed; 3= Awareness of feed type required for good production; 4= Awareness of the need for proper fodder storage; 5=Other (specify): //_________//

16. What difficulties did you encounter during the experiment: //____//

17. What are your recommendations for improving cow rationing in the dry season: //____//

18. General comments on the experiment: //_____________________________________//

6.4 Follow-up sheet for Efficient Covered Manure Pits (ECMPs)

Farmer Details

Farmer code: //_______________//

Name: //_______________//

First name(s): //_______________//

Village / MCC (1- Satiri ; 2- Dafinso ; 3- Kouakoualé ; 4- Bana ; 5- Bama ; 6- Farakoba ; 7- Belle ville ; 8- Benkadi ; 9- Yégueresso) : //_______________//
Manure pit's geographical coordinates: //_______________//
Type of pit (1- Built manure pit; 2- Manure pit not built): //______//

Pit construction monitoring

Tasks	Practice methods
Pit location	Type of pit (1- Field pit; 2- On-farm pit): //_______________// Barn/pit distance: //_______________// Farm/pit distance: //_______________// Water source (well)/pit distance: //_______________//
Soil type	Local name: //_______________// Gravel ☐ Sandy ☐ Clay ☐
Dimensions	Length (m): //__________________// Width(m): //__________________// Depth (m): //__________________//
Construction	Pit excavation date: //__________________// No. of family labour: //____________// No. of days for family labour: //____________// No. hours/day for family labour: //____________// Hired labour: Yes☐ No ☐ If yes No. of hired labour: //____________// No. of days for hired labour: //____________// No. hours/day for hired labour: //____________// Expenses (Fcfa): //____________// Pit construction date (stabilisation): //______________// Type of construction (1-Brick; 2-Stone): //__________________// Number of rows://_____________// Rendering: Yes☐ No ☐ Height of built-up edge: //____________// No. of family labour: //____________//

	No. of days for family labour: //___________// No. hours/day for family labour: //___________// Hired labour: Yes☐ No ☐ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//

Pit filling monitoring

Task	Practice methods
First filling follow-up	Date: //____________________// Pit filling level: (1 = 0%; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100%): //_________// OM breakdown level: • Visual assessment of breakdown level: (1 = 0%; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100%): //_________// • Presence of biological activity: Yes ☐ No ☐ • If yes, please specify: //_________// • OM temperature (°C): //_________// Origin of livestock co-products : • No. of dairy cows: //_____// • No. of other cattle: //_____// • No. of small ruminants: //_____// • Other, please specify Origin of crop co-products : • Forage refusal: Yes ☐ No ☐ • Coarse CCP litter (straw) : Yes ☐ No ☐ • Cotton stalk litter: Yes ☐ No ☐ • Household waste: Yes ☐ No ☐ • Other, please specify: Manure watering after filling: Yes☐ No ☐ • If so, please estimate water quantity (litres): //_____________// Pit cover after filling: Yes☐ No ☐
Second filling follow-up	Date: //____________________// Pit filling level: (1 = 0%; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100%): //_________// OM breakdown level: • Visual assessment of breakdown level: (1 = 0%; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100%): //_________// • Presence of biological activity: Yes ☐ No ☐ • If yes, please specify: //_________// • OM temperature (°C): //_________// Origin of livestock co-products : • No. of dairy cows: //_____// • No. of other cattle: //_____//

	• No. of small ruminants: //_____// • Other, please specify Origin of crop co-products : • Forage refusal : : Yes ☐ No ☐ • Coarse CCP litter (straw) : Yes ☐ No ☐ • Cotton stalk litter: Yes ☐ No ☐ • Other details : Manure watering after filling: Yes☐ No ☐ • If so, please estimate water quantity (litres): //_____________// Pit cover after filling: Yes☐ No ☐ Filling costs :
... until May 2023	…….
Turning operation	Manure turning date: //__________________// No. of family labour: //____________// No. of days for family labour: //____________// No. hours/day for family labour: //____________// Hired labour: Yes☐ No ☐ If yes No. of hired labour: //____________// No. of days for hired labour: //____________// No. hours/day for hired labour: //____________// Expenses (Fcfa): //____________//
Production assessment	Manure exit date: //____________// Quantity of OM Number of trips by type of vehicle : 1. Dumper: //____________// 2. Small flatbed cart: //____________// 3. Large flatbed cart: //____________// 4. Tricycle: //____________// 5. Dumper: //____________// 6. Covered: //____________// No. of family labour: //____________// No. of days for family labour: //____________//

	No. hours/day for family labour: //___________// Hired labour: Yes□ No □ If yes No. of hired labour: //___________// No. of days for hired labour: //___________// No. hours/day for hired labour: //___________// Expenses (Fcfa): //___________//
Destination of OM produced	Demoplot 2024: Cotton: Maize: Others:

Manure quality assessment

Tasks	**Conditions**
Visual appreciation	Date: //__________// Breakdown level (1 = 0%; 2 = 25%; 3 = 50%; 4 = 75%; 5 = 100%): //_________// Presence of biological activity: Yes□ No □ If yes, please specify: //_________// Presence of viable seed (arrange for germination tests to be carried out on OM samples): Yes□ No □
Chemical composition	Sample collection date: //___________// Dry matter content: //_________// Nitrogen: //_________// Phosphorus: //_________// Potassium: //_________// Calcium: //_________// Magnesium: //_________//