DETERMINATION OF BREEDING OBJECTIVES FOR SMALLHOLDER DAIRY CATTLE IN SENEGAL USING BREED AND TRAIT PREFERENCES, AND ECONOMIC ANALYSIS

BY

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DECLARATION

I declare that this thesis is my original work and has not been presented before in this university or any other university for the award of this or any other degree.

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DEDICATION

This thesis is dedicated to my Dad, Francis Ipenji Malenje (Frank) and my Mum, Janet Joseck Malenje (JJ) for their encouragement, prayers and support during my studies.

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LIST OF ABBREVIATIONS AND ACRONYMS

AI:	Artificial Insemination
AIC:	Akaike's Information Criterion
ANOVA:	One-way Analysis of Variance
B:	Benefit
C:	Cash costs
CFA:	West African Franc
GM:	Gross margins
HBT:	High *Bos Taurus*
HSD:	Tukey's Honestly Significant Difference
I:	Income
ILRI:	International Livestock Research Institute
IZ x BT:	Indigenous Zebu and *Bos taurus* cross
IZ x GZ:	Indigenous Zebu and Guzerat cross
IZ:	Indigenous Zebu
LMICs:	Low- and Middle-Income Countries
MX:	Mixed
NGO:	Non-Governmental Organization
NR:	Net Returns
OC:	Other costs
Pcpa:	Per cow per annum (pcpa)
Phpa:	Per household herd per annum
PNDE:	National Programme for Livestock Development
PSIA:	Special Programme for Artificial Insemination

R^2: Coefficient of determination

SLU: Swedish Livestock University

SSA: Sub-Saharan Africa

USD: United States Dollars

X^2: Chi Square

ABSTRACT

Across Africa, there is a need to identify the most suitable livestock breeds for specific livestock production systems. This identification is particularly important for livestock systems that are intensifying, and forms the starting point for genetic improvement strategies. This is pertinent in Senegal which has very low dairy productivity and subsequent net importation of dairy products. The objective of this study was to identify a breeding objective for smallholder dairy cattle keepers in Senegal by determining farmers' dairy cattle breed and trait preferences, and analysing the dairy cattle farming economics.

Baseline and longitudinal survey data from 257 and 220 smallholder dairy farming households was collected using questionnaires at two study sites (Thies and Diourbel), located in the Center-North of Senegal's groundnut basin. Pearson's Chi Square (X^2) was used to analyse counts of categorical responses on dairy cattle breed and trait preferences and Monte Carlo test using 10 000 replications used to compute the p-value at $p \leq 0.05$. Cattle breeds were assigned to breed type based on farmer recall as local, crossbreed or exotic. Further, using the Bovine 50K SNP chip, 624 cows that had full lactation records were genotyped for the breed assignment. The calculations for breed types' and household groups' Net returns (NR) were analysed using a One-way Analysis of Variance (ANOVA) and Tukeys post hoc approach.

There was a significant difference ($p=0.00$) in preference for cattle breed types, trait advantages and disadvantages for local, cross and exotic breeds among smallholder dairy cattle farming households. For all households, crossbreed cattle with the highest standardized residual (10.87), were preferred more than either local or exotic cattle. The main advantage of both the crossbreed and exotic dairy cattle was high milk yield with 9.53 and 6.17 standard residuals respectively. In contrast, the main advantage for the local breed of cattle was good adaptation to the local conditions with standard residuals of 14.06. The main disadvantage for the local breed of cattle was low milk yield with a standardized residual of 20.82. In contrast the main

disadvantages of crossbreed and exotic dairy cattle was high feed intake and poor adaption to local conditions with standardized residuals of 9.63 and 5.91 respectively. Although milk yield was the most important preferred cattle trait on the farm (rank=1), all named dairy cattle traits except sale value of calves and calf mortality were ranked first by some farmers. In this study there were significant differences ($p \leq 0.05$), in milk yield, feed consumption and breeding (as reproductive cost) between exotic breeds and either crossbreeds or local breeds.

Economic analysis of 113 dairy cattle keeping households showed that the mean *NR* per cow per annum (*pcpa*) was 21.7 USD. Only 52.2 % of the dairy cattle enterprises had a positive *NR*. The households grouped in 5 groups, (group 1 having least mean *NRpcpa* and group 5 having the greatest) showed that group 5's incomes from milk and animal sales were significantly greater at ($p \leq 0.05$) than the other 4 groups. Additionally, for groups 1 and 5, expenditures on purchasing animals, feed, and labour was significantly greater compared to the other groups at $p \leq 0.05$. Further, farmers in group 5 mainly raised the indigenous zebu by Bos *taurus* cross (IZ x BT) cattle breed type. Based on breed types, High Bos *taurus* (HBT) had significantly higher income from milk sale and expenses on purchase of feed, animals, water, animal health care and animal reproduction compared to the other 3 breed types. IZ x BT had significantly greater incomes from animal sale, milk consumed and cost of hired labour compared to the other 3 breed types at $p<0.05$. Although, the mean NRs of households grouped by the main breed-type were not significantly different from each other, the mean total income and costs were significantly higher for improved dairy breeds (HBT or IZ x BT) compared to IZ or IZ x GZ (Guzerat) crosses at $p \leq 0.05$.

There is multiplicity of trait preferences of dairy cattle keepers in Senegal. As a result, IZ x BT crossbreeds are preferred more. There is high variance in profits across the dairy cattle keeping households and almost 50%) made losses. This study recommends a breeding objective defined as ‘Improvement of milk and meat yield without loss of adaptable traits’.

Key words: Senegal. Breeding objectives. Milk yield. Crossbreed. Dairy cattle. Breed and trait preferences. Smallholder. Livestock. Net returns

CHAPTER ONE: INTRODUCTION

1.1 Background information

1.1.1 The dairy sector in Senegal

Senegal is a semi-tropical country and the most westerly country in West Africa (Khouma, 2013). It has a population of about 17.4 million people with 52.8% of them living in rural areas (FAOSTAT, 2022; UN, 2022). In Senegal, milk is a commodity of significant economic and nutritional value (Bernard *et al.,* 2019; Chengat Prakashbabu *et al.,* 2020; Craighead *et al.,* 2021). Senegal imports substantial amounts of dairy products, with the value of milk (including fresh, dried, and other formulations of milk) imports in 2019 exceeding 43 million US dollars (FAOSTAT, 2022). The imported cheaper milk presents some problems 1. It comprises of powdered milk, vegetable fat (mainly palm oil) and skimmed milk and is therefore of standard quality with lower nutritional value than whole milk and 2. It may be environmentally unfriendly as it is a product of industrial farming (dairy and palm oil) and 3. It limits job opportunities in the importing countries (Finnegan *et al.,* 2017; Duteurtre *et al*., 2020). In 2020, the national milk production in Senegal was estimated to be 247,152 tons, with cattle contributing 89.3% of the total milk produced. This production was mainly for subsistent use and for sale at local markets (Duteurtre *et al*., 2020; FAOSTAT, 2022). Although national milk demand is still above the local milk production, there has been a significant growth in local milk production, for instance, as evidenced by an increase by approximately 66% between 2008 and 2018 (FAOSTAT, 2021). Local milk production is from cattle, goats, sheep and camels, with cattle making up the bulk (88% of the output in 2018) (FAOSTAT, 2021). Even though Senegal has a relatively large cattle population for its geographical size, estimated around 3.7 million head in 2019, it only produces about one-third of its country's fluid milk needs (FAOSTAT, 2021).

1.1.3 Dairy cattle production systems in Senegal and initiatives to strengthen it

In Senegal local milk production is dominated by extensive traditional pastoral systems although mixed semi-intensive dairy farms and intensive and specialized milk farms are mushrooming around peri-urban areas and cities (Broutin *et al*., 2018). Local cattle of low milk production potential, which characterize the extensive systems usually graze freely on communal land. Exotic and cross (indigenous x exotic) breed animals with appropriate animal management practices in respect to animal feed are also becoming more prevalent, especially in Dakar's peri-urban districts (Marshall *et al*., 2017).

The Senegalese government has over time aimed at strengthening the dairy industry through various initiatives. For instance, in 2013, the Programme for National Livestock Development (PNDE) emphasized the value chain for milk through initiatives centred on livestock keepers' capacity building, food security, and genetic improvement. A National Dairy Committee was established, milk collecting efforts were enhanced , and artificial insemination (AI) of dairy animals, using exotic breeds genetic material, was implemented (Seck *et al*., 2016).

1.2 Statement of the problem

Substantial importation of milk has suppressed the development of the local dairy farming in Senegal. There is a need to identify breeding objectives for future breeding programs that includes appropriate breed types and the traits as a key starting point (Kor and van der Waaij, 2015) for the Senegalese dairy sector’s goal of improving local dairy productivity and the substitution of imported milk.

1.3 Justification

Since the 1970s, tax-free powdered milk imports have offered a simple way to satisfy Senegal's expanding urban demand for dairy products. The limitations of this strategy have been revealed by the rising volatility of agricultural commodity prices, which has been particularly high over

the past ten years (OCDE/FAO 2017). Local milk production has garnered fresh interest from national authorities and private dairy companies as a result of unpredictable powdered milk prices and the explosive expansion of urban demand. The government's main worries include macroeconomic imbalances, rural poverty, and the availability of dairy products for the urban population brought about by dairy products' importation (Magnani *et al.,* 2019). Despite the government's effort to fund a number of initiatives that promote local dairy production, there is inadequate evidence base on which breeding objectives to promote in future dairy genetic breeding programmes. For the Senegalese context, calculating the variance in profit from keeping of different cattle breed-types by performing intra-household benefits analysis (as opposed to breed-type alone, as has been done by (Marshall *et al*., 2017) is useful for decision making by policy makers and other stakeholders on which breed-type to promote for profitable dairy ventures.

1.4 Objectives

1.4.1 Overall objective

To determine smallholder dairy cattle breeding objectives by examining breed and trait preferences, and the economics of the dairy cattle keeping based on profit levels and breed type.

1.4.2 Specific objectives

1. To determine smallholder dairy cattle breed and trait preferences in Senegal
2. To determine the profitability of dairy cattle keeping and compare them based on cattle breed types

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview of the dairy sector in Senegal

In Senegal, local milk production is mainly from cattle. Other species which produce milk for local consumption include goats, sheep and camels. The average milk in tonnes from Cattle, goats, sheep and camels between 2017 and 2021 was 220977.8, 14855.1,12319.3 and 537.5 respectively (FAOSTAT, 2023), Figure 1**.**

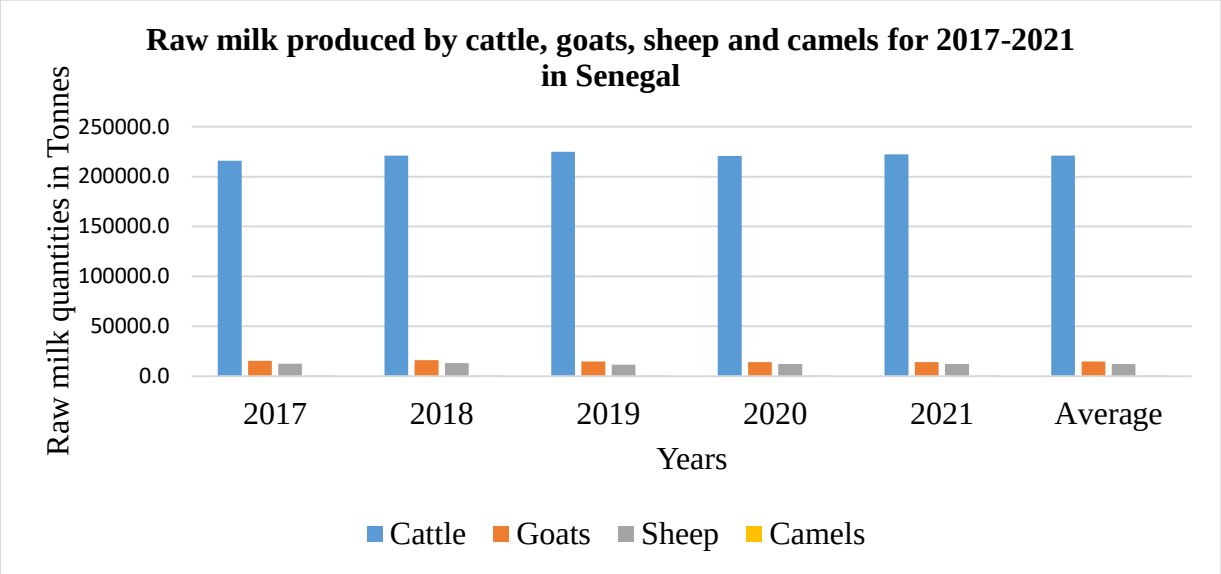


Figure 1: Raw milk (tonnes) produced by cattle, goats, camels and sheep between 2012 and 2021 in Senegal.

According to (FAOSTAT, 2023), the amount of raw milk produced from cattle in Senegal had been steadily increasing for the period of 5 years between 2017 and 2021. The average quantity was however very low, accounting for only 0.54% of the total milk produced in Africa and 0.03% of that produced in the world (FAOSTAT, 2023) Table 1. The Senegalese local cattle breeds produce 300 litres per cow per year which is far below the average of 7000 litres for European breeds (Cécile, 2018; Karen Marshall *et al*., 2017; Seck *et al*., 2016). Further, in Senegal, cattle are multipurpose animals providing milk, meat, draft and serve in cultural functions.

Table 1: Total raw milk produced from cattle for Senegal, Africa, Europe and the World in tonnes

Year	Senegal	Africa	Europe	World
2017	216000.0	38291433.9	221094663.2	685198734.1
2018	221000.0	38926141.6	223546332.2	701298804.4
2019	225000.0	40700869.0	224911775.0	715046737.0
2020	220666.7	42650324.1	227538396.0	742425787.6
2021	222222.2	42509419.2	226559635.7	746056588.8
Average	220977.8	40615637.6	224730160.4	718005330.4

(FAOSTAT, 2023)

2.1.1 Milk production systems in Senegal

Senegal has three primary dairy production systems. The traditional, semi-intensive and the intensive production systems. The traditional production system is situated in the regions of the North and North Central; both situated in silvopastoral and river valley regions, correspondingly. During the dry season, transhumance is a defining feature and it generates 38% of the country's milk production. (Dia, 2009). The milk in this system is mainly for consumption and the surplus is sold at local markets. The continuous production of milk throughout the year is the focus of the semi-intensive system, which is an improvement over the traditional system. Important semi-intensive cattle production areas include the Kolda, Ziguinchor, and Tambacounda districts. They have substantial rainfall and rich natural vegetation, leading to low production costs (Diouf, 2012). In this system, selling 25% of the milk serves as a supplemental revenue stream. The intensive production system utilizes temperate cattle breeds for milk production, using biotechnology and hired labour. It is primarily found in sub-urban zones around Dakar and milk production levels are higher due to high input levels especially feed (Diouf *et al.*, 2016: GRET, 2022).

2.1.2 Local cattle breeds found in Senegal

In Senegal, the primary method used to boost milk production from cattle has been crossbreeding. The first studies done to crossbreed were in 1964 where low-yielding native breeds were crossed with high-yielding exotic breeds (Seck *et al.,* 2016). N'Dama Taurine, Djakoré, Maure zebu and Gobra zebu are four native cattle breeds in Senegal. They can be found in a variety of agro-ecological systems, from the Sahelan to the Soudano-Guinean climate. The Gobra zebu was brought to Senegal in the second half of the ninth century from the Fouta Toro Basin. The Maure zebu, on the other hand, is a species that is typically found Niger loop, Mali and Mauritania. It is bred specifically in the Senegal river basin along the Mauritania border. In comparison to Gobra, the Djakoré cattle are around the same size and have a faint hump. It is believed to be as a result of natural crosses between Gobra zebu and N'Dama based on its morphological traits and geographic distribution (Ndiaye *et al.,* 2015).

2.1.3 Consumer trends and preferences of dairy products in Senegal

Senegal's meagre domestic milk output only meets 55% of the country's population's needs (30.2 L per person) (MEPA, 2018). To cover the shortage, there is a substantial dependency on imported milk and milk products (Salla, 2017). The dairy industry is divided into two primary segments: local dairy production and processing from traditional agro-pastoral communities; and imported dairy goods, particularly powdered milk (GRET, 2022). In recent years, attempts to decrease dairy imports and increase domestic production have largely failed. The prediction is that milk consumption in Senegal will consistently rise (Dieye *et al.,* 2005; Boimah and Weible, 2021). However, rather than domestic milk production, imports from European nations are supporting the surge. Additionally, Senegalese businesses' packaging and shipment of overseas milk powders hinders the development of local milk marketing and production (Leone *et al.,* 2022). In Senegal, consumers strongly prefer locally produced, domestically processed milk over imported milk due to quality attributes. However, consumers choose imported milk

and milk products because they are cheaper, readily available and more varied (Boima and Weible, 2021).

2.1.4 Dairy genetic improvement in Senegal: Past, current and existing challenges

Since 1995, the Senegalese government has been sponsoring national AI programmes and has established regulatory structures to oversee the numerous dairy genetic improvement interventions. In addition to the AI programme, over the past years, there has been temperate cattle breeds importation into Senegal. The programme's goal has been to increase milk production by revamping the local cattle genetic makeup (Diouf *et al*., 2016). Setting up of the National Dairy Committee and initiatives on enhancement of milk collection are other state backed initiatives supporting the AI programme for dairy cattle (Seck *et al*., 2016). Consequently, some cattle keeping households in Senegal have increased their focus to raising pure exotic dairy cattle or, less frequently, crossbred exotic and native dairy cattle. Despite these efforts, previous genetic improvement for dairy cattle in Senegal have been futile due to the reasons below:

1. Indiscriminate cross-breeding of local and temperate breeds devoid of guidelines to maintain appropriate temperate breed blood levels including lack of dam line selection, and/or overdependence on breed replacement.

2. A mismatch between introduced genotypes and farmers' breeding objectives, husbandry activities and environmental conditions

3. Paucity of comprehensive approaches of designing modest yet efficient breeding methodologies as opposed to embracing sophisticated breeding programmes that demand numerous coordination with invention, and

4. Inadequate or lack of systematized evaluation of breed research to ensure unbiased comparison of the relative advantage of local and temperate breeds under characteristic conditions due to genotype x environment interaction.

Further, minimal animal numbers per household typical of smallholder production systems, herds with a single-sire, lack of performance and pedigree records, lack of systematized animal identification, illiteracy, inadequate infrastructure, and dysfunctional institutions complicate the Senegalese situation further (Diouf *et al*., 2016). Although the potential for growth and demand for germplasm provided by commercially owned companies is high, Senegal continues to have minimal use of AI and cross-bred or exotic cattle (Seck *et al*., 2016). Other challenges that counter efforts made to improve dairy genetics in local cattle include: the mobility of pastoral herds which present additional challenges to animal selection and recording (Wurzinger *et al*., 2006), low AI's success rate caused by animals in too poor condition to conceive due to insufficient and poor quality feed (Cabral, 2016), and inexperience of the AI service providers. Generally, although dairy cattle farming in Senegal is fast intensifying, production and productivity at smallholders' levels are still low. To be able to address the plethora of gaps enumerated above, it is important for the dairy industry to set up dairy cattle breeding programmes backed up by evidence from research for sustainability purposes.

2.2 Breeding objectives and their importance in breeding programmes

A breeding objective defines the traits that need to be changed and the direction of the changes (Huţu *et al*., 2020;Wahinya *et al*., 2022). Generally, the breeding objective may be to maximize profit, increase economic efficiency, or reduce economic risk. However, a breeding objective need not to be economic for instance where companion animals are involved. Generally, the purpose of a breeding objective is to maximize animal profitability while maintaining the animals' health, welfare, and environment (Simm *et al*., 2020). At the beginning of genetic improvement programmes, defining breeding objectives is the first step (Fewson, 1993; Urioste

et al.,1998; Kor and van der Waaij, 2015). Gizaw *et al.*, (2010) suggested that four steps ought to be followed in the identification of breeding objectives namely: defining the marketing and the production systems, identifying the expenses and revenue sources, identifying traits to be included in the breeding objective i.e. biological traits influencing costs and revenue, and economic value derivation of each trait in the breeding objective.

In the past, the majority of within-breed selection programmes focused on raising yield while paying some consideration to cow breed and conformation. The introduction of milk quotas as a means of controlling national production and limiting support costs increased emphasis on milk composition in payment schemes in many countries. This introduction also resulted in actual or perceived negative effects of yield selection on health, fertility, and welfare leading to an increase in interest in broader breeding objectives and indexes (Simm *et al*., 2020). The focus on milk output in comparison to milk components and traits related to health, fertility, and welfare has changed throughout time as a result of these and other technical advancements. (SRUC, 2018) identified milk, sale of calves and/or culling, feed and animal health as the main factors to be considered when defining sustainable breeding objectives for dairy production systems. This is explained in more detail below.

In both high and low-input production systems, milk production returns are the most significant returns. For most temperate nations, the primary objective criterion for choosing between and among dairy breeds over time has been milk output (Simm *et al.*, 2020). Selection between and within breeds, as well as improved nutrition and health management, have resulted in significant modifications recently. Although milk yield is a significant factor in profitability, it has gained particular attention since it is easier to evaluate than other factors (Simm *et al.*, 2020). In general, European buyers who specialize in liquid milk sales tend to place less attention on milk composition than buyers who specialize in processed dairy products. This variation in payment plans may justify differing breeding objectives for producers selling into

various markets. Nevertheless, as demonstrated in national breeding objectives of many countries, distinct goals are not essential due to the substantial genetic relationship between total milk output and yield of protein or fat. Despite modifications in many nations' selection indices, qualities related to milk production continue to receive a lot of attention. One of the reasons for this, according to (Hubbart *et al.,* 2023; Kaniamuthan *et al.,* 2023), is that the breeds and individuals with the greatest milk yields are typically the most effective at converting feed energy into milk energy. In their study, high yielding breeds like the Holstein Friesian not only consumed more feed, but they were also more effective at allocating resources to milk production than to body reserves, which led to a decrease in weight and condition score. Although (Oldenbroek ,1986) has shown that the Jersey breed had a better efficiency than anticipated for this yield, it does appear to be an outlier. Indicating that compared to other breeds, the Jersey breed produces and consumes more per unit of body size.

On animal sale, (SRUC, 2018) found out that lower returns were realized from both low and high input production systems but this is more crucial in low input systems than in the high input systems. Historically, one of the major outputs of the dairy businesses has been the sale of calves for meat. Dairy bulls entering progeny testing for milk production in temperate zones are first put through a performance test for beef traits. Due to the extensive usage of beef x dairy sucker cows, the dairy and beef sectors are becoming further more interconnected in several of these nations. As a result, the benefits of breeding for dual purpose over more specialized dairy cows have been a topic of discussion. A study by (Ledinek *et al.*, 2019) showed that dairy-specific black and white Holstein strains were more lucrative than strains with multiple uses. This explains why the majority of European and temperate nations have chosen the specialization route. In this situation, mating the cows who aren't needed to produce replacement calves to beef bulls would often maximize the profits from the surplus calves. A beef bull may breed with as many cows as possible, which increases the amount of money that

can be made from selling beef-cross calves. This is made possible by good fertility and a short calving time. Additionally, using sexed semen means that fewer matings are needed to produce substitute dairy heifers. Additional chances to boost profits from the sale of beef calves or pure beef calves may also arise as a consequence of advancements in these procedures and in low-cost methods of sexing and embryo transfer (Simm *et al.,* 2020). The decision of sire within a beef breed as well as the choice of beef breeds themselves have an impact on profitability.

In regards to feed, except for the importance of concentrate vs forage costs, which varies between the systems, feed costs are the most important expenses in both high and low input production systems. Until recently, most dairy cow breeding plans did not consider feed intake or efficiency as part of the breeding aim due to difficulties in monitoring intake. With the current evidence that better yielding dairy breeds are more efficient converters of feed energy to milk energy, this is now a common practice. It is also difficult to determine whether breeding efforts should try to raise or decrease feed intake due to debates about whether intake influences yield or vice versa and the significance of maintaining the potential for high roughage intake in ruminants (Simm *et al.,* 2020).

Direct health expenses seem to make up a little portion of profits (SRUC, 2018). However, the secondary costs associated with missed productivity and the consequences of sickness for animal welfare show that genetically enhancing health requires more attention than a cursory economic study may imply. In a similar vein, the indirect costs of reproduction seem to be very low, although they are also accompanied with direct costs (Simm *et al.*,2020). As a result of selection for yield, there is evidence of genetic decrease in certain areas of health and reproduction (Tohidi *et al.,* 2023; Gonzalez-Recio *et al.,* 2023), necessitating effort to change this in many nations. As a result, more comprehensive national selection indexes have been created, which take performance and other qualities linked to health and reproduction into account.

Although there is extensive proof that better yielding breeds and animals within breeds have higher gross efficiency, in recent decades it has become clearer that more comprehensive breeding objectives for dairy cattle need to be established (Simm *et al.,* 2020). A breeding objective can be as straightforward as a breed type, or more complex such as milk yield + feed efficiency + disease tolerance + docility. Additionally, some breeding objectives can be quantitative while others are qualitative.

2.2.1 The aggregate genotype

In all cases, changing more than one trait is required to attain the aggregate genotype in a genetic improvement programme (Kumar *et al.,* 2022; Bengtsson *et al.,* 2022). After defining the breeding objective, it is critical to specify the relative significance of the traits that need to be modified (Burrow *et al.,* 2019; Brito *et al.,* 2021). This entails first deciding which qualities may be genetically enhanced, followed by calculating the economic value (also known as the economic weight) of each trait improvement. The aggregate genotype of a particular animal that is a candidate for selection is defined as the total of its additive genetic values multiplied by the economic weight of each characteristic (Gaynor *et al.,* 2021; Houston *et al.,* 2020) i.e

Equation 1: Aggregate genotype determination

$$\mathbf{G} = a_1 b_1 + a_2 b_2 + a_3 b_3 \ldots . etc$$

Where **G** is the aggregate (economic) genotype, etc a_1, a_2 are economic weights of traits 1, 2, etc, and b_1, b_2 etc are the additive genetic values of traits 1, 2, etc., for however many traits are included.

2.2.2 The selection index

The genetic worth of the numerous traits for each animal's additive genetic makeup is unknown in practice. However, it is possible to track how each animal performs for a variety of traits. A

selection index, I, may then be created using the observations of these features (Berghof *et al.,* 2019) as shown below:

Equation 2: Selection index determination

$$H = d_1 y_1 + d_2 y_2 \ldots . d_m y_m$$

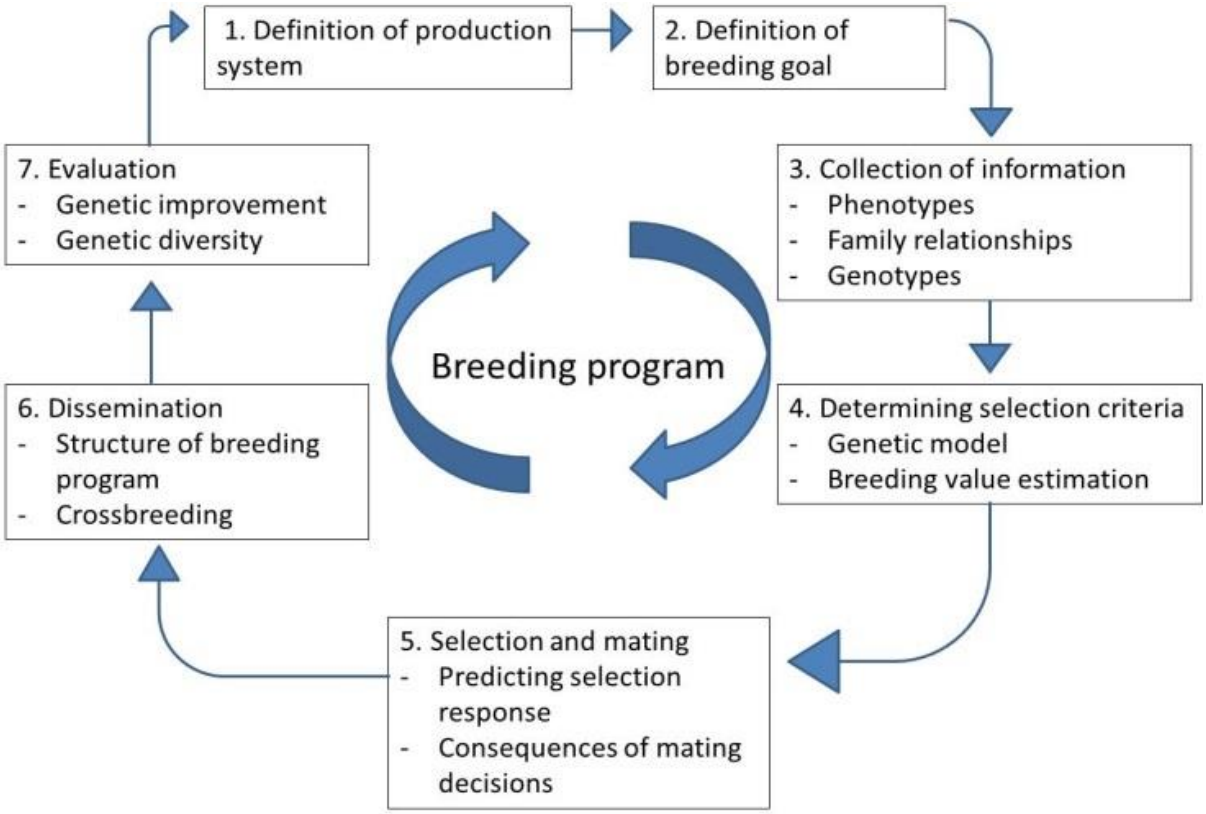
where y_1 is an observation on the H [th] trait and d_1 is the selection index coefficient (or weight) for that trait. The same logic holds true when a set of estimated breeding values (EBV) from a genetic evaluation programme is supplied, rather than performance data for each individual. H in this case can be referred to as the selection objective since it combines the traits and their economic values (Cameron, 1997)

2.2.3 The breeding programme cycle

Numerous factors have an effect on breeding challenges. The factors include: the wants and needs of the people who own the animals, the people who buy animal products, the food business, and increasingly the general public. Setting up successful breeding programmes necessitates anticipating future situations and meticulous planning in order to strike the correct balance between the many demands. The breeding objectives and breeding programmes are greatly influenced by the use of the animals and the desires of the users (Lund *et al.,* 2023). In addition to selective breeding for the obvious breeding objective traits, other traits play a significant role in breeding programmes for animal functions other than food production (Kor and Liesbeth, 2015; Chasama *et al.,* 2023). These traits include animal health and welfare, adaptation to low-quality feed and harsh climates, and the ability to procreate. Many questions regarding the production system must be resolved prior to determining the breeding objective. What use does keeping the animals serve? Which methods are used to market the animals and the animal products? What are the crucial elements of management and feeding? Are the breeders organized? Is there a breeding plan in place already? What traits can be recorded? Is it possible to reproduce artificially? The potential for breeding programmes and the choice of

breeding objective qualities are thus determined by these features of production systems (Kor and Liesbeth, 2015).

The first stage in starting a breeding programme should be selecting the breed that will perform best in a particular habitat or production system, with due consideration for a breed's capacity for adaptation. Due to their evolutionary background, regionally adapted native breeds exhibit a far higher level of resistance and adaptation than imported breeds (Sonesson *et al.*, 2023). Since a breeding objective targets the future, breeding objective traits may be limited to the breeder's preferences, to the demands of producers and processors, or they may be expanded to include consumer behaviour or society preferences. However, the more traits included in the breeding objective, the less the progress for each trait per generation. A breeding programme's results are frequently observed many years after selection decisions have been made. This highlights the importance of considering future demands when defining breeding objectives and calls for consideration of returns on investments. And it takes several generations of selection to achieve the majority of breeding objectives. Breeders involved must be tenacious in order to achieve this, as frequent modifications to breeding objectives obstruct the advancement of breeding programmes. Below is a systematic illustration of all the steps of a breeding programme.



(Kor and Liesbeth, 2015)

Figure 2: The systematic steps of a breeding programme

2.3 Use of breed and trait preferences to determine breeding objectives

In Sub-Saharan Africa (SSA), most smallholder dairy farmers have multifaceted breeding objectives hence both the economic and the non-economic value of livestock need to be considered (Bebe *et al.*, 2003).The goal should be to obtain high yielding dairy cattle (that can meet the high milk demand especially in urban and peri-urban areas which are home to about 50% of the Senegalese population (Wilson, 2018). The animals should be appropriately suited to the challenging tropical climatic circumstances that they must perform in. Elite inhabitants of such areas with better purchasing abilities, food habits and preferences are forecasted to increase the demand for livestock related products by 25% by 2025 (Delgado *et al.*, 2020). This has in turn made land use patterns in peri-urban and urban areas of Senegal to change. Mugisha *et al.*, (2014) notes that for adequate returns to be realized and to control breeding and exploit

improved breeding systems, such land use change should be followed by keeping a few but high-grade animals with breeding practices that are aligned towards genetic improvement.

In East Africa where comparative patterns have been observed, strengthening native genetic resources which fit well to the livestock system has gained traction in recent decades and is recognized as a more viable choice (Haile *et al.,* 2019; Abebe *et al.,* 2020; Kaumbata *et al.,* 2020; Sila *et al.,* 2021). In order to meet production system demands, farmers seek breeding stock with specific qualities, features, or traits which best serve their interests or best match their situation and goals. Since the farmers are part of a production system, various factors influence the availability and accessibility of desirable genes as well as their distribution methods (breeding services). These aspects affect farm-level breeding decisions and may have an impact on the expansion of the dairy genetic pool and smallholder dairy production in general (Mugisha *et al.,* 2014). In Sub-Saharan Africa including Senegal, there is lack of information on the individual animal characteristics favoured by smallholder farmers (Chawala *et al.,* 2019). In East Africa, various projects under the International Livestock Research Institute (ILRI) to identify vital traits which smallholder farmers prefer when selecting dairy cattle have been conducted. They include: East Africa Dairy Development, Tanzania Dairy Genetics, More Milk-IT and Dairy Genetics East Africa (DGEA, 2015).

2.4 Other methods of identification of breeding objectives

Apart from participatory approaches which are often used to identify breeding objectives (Duguma *et al.,* 2011), bio-economic models (Laske *et al.,* 2012; Lopes *et al.,* 2012; Gunia *et al.,* 2013;) and profit functions are other methods. In livestock production systems bio-economic modelling involves incorporation of a number of human decision making aspects and modelling their effects using mathematical relationships originating from both economic and biological guidelines (Rewe and Kahi, 2012). In a study by (Marshall *et al.,* 2020) in Senegal a bio-economic model was used to determine the financial viability of different household dairy systems based on level of management and the cattle breeds reared.

On profit function, the cost-benefit analysis theory for livestock breeding programmes was developed by (Hill, 1971; Moav, 1973; Weller, 1994; Wilton *et al.* 2013) and profitability is a key determinant of selective breeding in breeding programmes (Hollenbeck and Johnston, 2018). According to (Sørensen *et al.,* 2008), in specific production systems, livestock improvement aims at increasing the frequency of desirable gene combinations in traits that are economically important, which in turn increases profitability. The degree of this profitability is somewhat determined by the weight given to each trait in the breeding aim. This is so because the traits used to determine the breeding objective serve as the foundation for developing the profit function, which is the source of economic values (Abraham *et al.,* 2018; Janssen *et al.,* 2018; Ogawa *et al.,* 2021). Economic weights, which are calculated as the anticipated increase in herd yearly profit per unit increase in trait as a result of selection, are used to determine the economic significance of biological traits in breeding (Júnior *et al.,* 2007). It is important to note that the genetic development of smallholder low input cattle systems should be handled differently than in standard elite seed stock breeding programmes, considering, in addition to market variables and the environmental production system, their production and societal way of life.

2.5 Importance of disaggregating livestock breeds and trait preferences by gender

In setting a breeding objectives, good comprehension of the farming system, farmer roles and existing institutional organization is pivotal before coming up with genetic improvement activities (Yakubu *et al.,* 2020). Studies by (Teeken *et al.,* 2018;Tufan *et al.,* 2018) have shown that in agricultural research it is important to understand the preferences of different stakeholders including gender and different socio-economic groups. To achieve value for money and because selective breeding programmes are tedious, it is critical that clients' livestock preferred traits are explicitly identified including the existing breeding practices since both men and women are involved in livestock rearing (Salomon, 2015; Yakubu *et al*., 2020).

Livestock interventions can play an important role in improving gender equality since rural women make up approximately 50% of the global poor livestock keepers (Staal *et al.,* 2019; FAOSTAT, 2021). Men and women have disparate access to and authority over production resources on which livestock keeping relies. This makes gender to be of significant impact on livestock ventures especially in developing countries (Tegbaru *et al.,* 2020). Further, differences associated with gender influence the way livestock are used at household level, at markets and how they are valued by different groups of consumers. Previous studies such as (Slagboom *et al.,* 2016; Laborte *et al.,* 2015) have shown that traits preferred by different farmer categories are manifold and depend on factors such as production systems, farm characteristics, and farmers' production objectives. Both genders can choose and keep the similar breeds in the same or different circumstances for numerous reasons. They may also have different trait preferences influenced by the different constraints they face, varying duties and responsibilities in production and consumption systems, and varying livestock production goals (Marshall *et al.,* 2019).

When gender trends are taken into account, efforts to boost livestock output and profits can help achieve a number of development goals, such as bettering women's status, improving child nutrition and health, and reducing asset accumulation discrepancies (Njuki *et al.,* 2016). Women, as main carers, invest a bigger portion of their income on food, a study by O'Brien *et al.,* 2016) showed that women spend up to ten times as much as men use on their families' welfare, as well as on nutrition, education, and health of their children (Duflo, 2012; Maertens and Verhofstadt, 2013). However, in many settings gender is seldom integrated in livestock improvement programmes (Kariuki *et al.,* 2022).

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area

The research was carried out in the Senegalese regions of Diourbel (Mbacke and Touba departments) and Thiès (Khombole and Tivaouane departments). These regions are located in the Center-North region of Senegal, in an agro-pastoral production system often known as the Peanut basin. The areas have a Sudano-Sahelian climate, which is hot and dry with a protracted dry season from October to June and an annual rainy season that lasts just approximately three months (Ngono-Ema *et al.*, 2018). The average annual rainfall is about 400mm. Acacia species is the dominant natural vegetation (Rasmussen *et al.*, 2011). The two research areas have seen varying degrees of dairy farming expansion, such as the adoption of temperate cattle lines mostly via state AI initiatives and improved nutrition methods (Seck *et al.*, 2016). The Senegal Dairy Genetics Project selected these sites because they had a high range of dairy cattle breeds (Marshall *et al.,* 2020; Ngono-Ema *et al.,* 2018). Below is a map of the republic of Senegal generated using the ArcGIS Software showing the study sites.

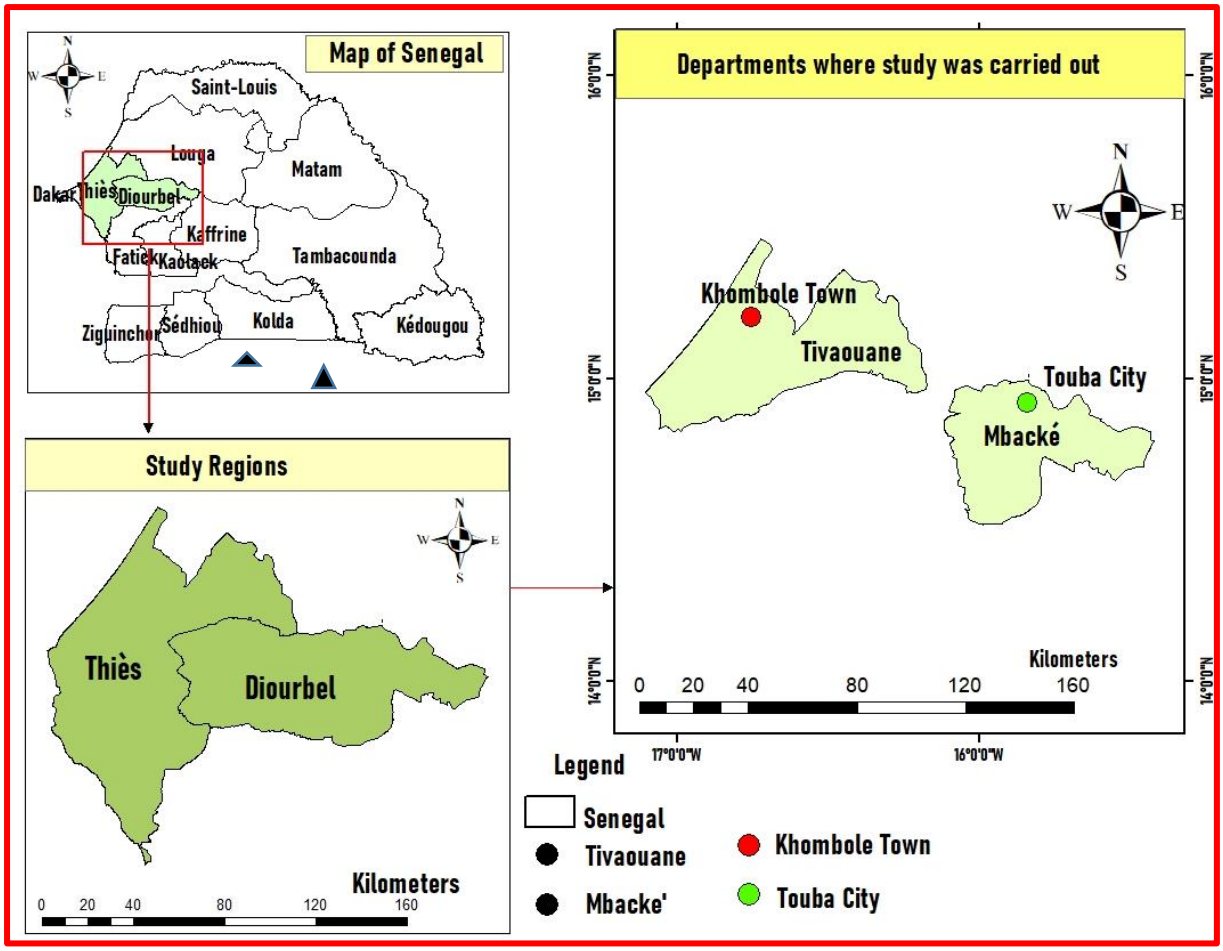


Figure 3: A map of the study regions and departments

3.2 Data collection

The data used in this thesis was collected by the Senegal Dairy Genetics project (https://senegaldairy.wordpress.com/) whose aim was to utilize the most suitable breed types to enhance the Senegalese dairy production and productivity. Between May and July 2013, baseline surveys were conducted, and between July 2013 and April 2015, longitudinal surveys were conducted. **Section 3.3** details how the final number of households was determined. 507 people, including 236 men and 271 women, were interviewed for the baseline survey. Respondents in the baseline survey included the household head, other household members (both male and female) and cattle herders (mainly male) for specific questions as was deemed appropriate. The baseline survey gathered data on preferred dairy cattle breeds and traits as

well as general data on the households (such as household composition, means of subsistence, and asset base (Marshall *et al.,* 2020).

Through structured (closed ended) questions (**Appendix 2**) in individual interviews, the respondents provided information on ownership of non-local breeds, cattle breeds kept, dairy cattle breed and trait preference. Specifically, concerning traits, respondents were first asked to identify which traits (from a predefined list) were of importance to them. Then they were asked to rank the traits that they indicated were of importance from most important (ranking = 1) to the least important depending on the number of traits they considered important. Tied ranks were also allowed. In addition, the respondents were asked to name the cattle breed types that they owned, managed or knew. These were categorized into three main categories, i.e., local breeds (Zebu Gobra, Zebu Maure, Djakor, or Ndama), indigenous zebu x exotic breeds, and exotic breeds (Holstein Friesian, Jersey, Girolando, or Guzerat). This was followed by ranking each breed type kept based on preference (with options of high, moderate, low or indifferent). The respondents were also asked to name up to 3 main advantages and 3 main disadvantages for each breed type, See **Appendix 2** with specific questions and possible responses on ranking, breed types, preference, breed advantages and disadvantages.

Additionally, during both longitudinal and baseline assessments, a range of data was collected. This included animal level information such as reproductive events, production quantities for milk and animal movements (like purchasing and selling); and information on household dairy enterprise economics (costs and benefits). Thirteen visits were made to the households at about equal time intervals during the longitudinal surveys. Information for the time period going back to the prior visit was gathered during these trips. The data was collected by a team of trained enumerators in Wolof, a local language in the study sites (Marshall *et al.,* 2020).

3.3 Household selection

The following were the criteria used to pick households for the study. A list of dairy cattle-keeping households (618) were identified within the locations using information provided by key informants (such as service providers, personnel from the Senegalese Ministry of Livestock, as well as dairy cattle keepers themselves).This inclusion was also based on their willingness to participate in the study and their ability of their herds to represent the widest variety of cattle breeds. They were asked basic questions regarding their household dairy business, such as how many cattle they had and what breeds they were.

For breed and trait preference analysis, 257 households that participated in the Senegal Dairy Genetics project baseline survey were considered while for the economic analysis, 220 households that kept dairy cattle were examined. The other households were excluded for various reasons, such as not being able to complete the survey. For the purposes of this study, a dairy cow was defined as an animal producing milk for human consumption (It is notable that many of the cows kept were for dual-purposes). In most cases, households kept more than one category of cattle (defined as local, crosses and exotic breed types), and households were purposely selected such that the overall set of households in the project were diverse as to regards cattle breeds-types kept (Marshall *et al.,* 2020). For the economic analyses the following number of households were excluded for the reasons listed: 51 households, for having been transhumant during the survey period making it impossible to collect full data, 26 households for not having full data for other reasons such as voluntarily dropping out, 14 households for not having a lactating animal in the survey period and 16 households for having a net return (NR) element e.g an expense or gain with a standard deviation value of 3.5 below or above the mean of the NR component. This was to avoid bias trends in the subsequent analysis which would result from these outliers. Finally, 113 households were considered for inclusion in the economic analysis. It should be noted that 6 additional households were

excluded from the analysis involving the comparison of breeds considering that they either lacked a dominant breed type or raised breeds other than the dominant breeds under study. since they either did not have a primary breed-type or raised breeds other than the dominant breed-types being examined. All included households offered to participate in the study voluntarily.

Table 2: Sample size determination criteria

Number of households	**Description**
618	Identified within study sites to take part in the baseline survey. Identification was based on information provided by key informants (such as service providers, employees of the Senegalese Ministry of Livestock, as well as dairy cattle keepers themselves
361	Dropped out for not being able to complete the survey for reasons such as not willing to share information.
257	Took part in the baseline survey. 507 respondents (236 male and 271 female) interviewed for information on breed and trait preferences.
37	Only participated in baseline and dropped out
220	Proceeded to the longitudinal survey.
51	Excluded from the analysis. Went on transhumance during survey and could not provide data for some rounds
26	Excluded from analysis. Full data could not be collected e.g lack of interviewee on interview dates
16	Excluded from analysis. Being an outlier for dairy cost or income components
14	Excluded from analysis. Lacking a lactating animal during the longitudinal survey
113	Included for the economic analysis
6	Excluded from the analysis. Lacking a main breed type
107	Included for the comparison of breed types

3.4 Data analysis

R statistical package was used. R is a language and environment for graphic design and statistical computing. It is a GNU project that is comparable to the S language and environment that John Chambers and colleagues created at Bell Laboratories (previously AT&T, now Lucent Technologies). GNU is a computer operating system that upholds users' freedom since it is free software. The GNU operating system is made up of both free software made available by other parties and GNU packages, which are tools exclusively distributed by the GNU

Project. The invention of GNU increased user freedom by enabling computer use without software. R could be thought of as an alternative S application. Although there are some significant differences, much of the code created for S works flawlessly under R.

R offers a wide range of graphical and statistical tools, including analysis of time series, categorization, grouping, and linear and non-linear modelling. It is also very extendable. R offers an Open Source (OS) alternative for those interested in participating in statistical methods research, which frequently uses the S language as its preferred vehicle. The simplicity with which well-designed charts of publication-quality may be created using R, complete with equations and formulas where necessary, is one of its strengths. The user still has complete power despite careful consideration being given to the graphics' minor design decisions' defaults. R is accessible as Free Software under the provisions of the GNU General Public License from the Free Software Foundation. On a wide range of UNIX platforms and related systems (including FreeBSD and Linux), Windows, and MacOS, it compiles and executes. R package has previously been used by (Gaynor *et al.*, 2021) for simulation of breeding programmes.

Specifically, R Core Team (2021) was used to analyse all the data. The denominator used to calculate breed and trait preference percentages was the number of responders to that given query (which differed because some interviewees chose not to reply to some survey questions and because respondents only provided information about the breed they owned). See Table 3. Pearson's Chi Square in R Core Team (2021) was used to compare counts of categorical responses between male and female respondents. This would enable examination on whether the association is due to gender of the respondents or is due to chance. Monte Carlo test (Hope, 1968) using 10 000 replications was utilized to compute the p-value and a significance degree (α) of 0.05 utilized for all significance tests. Monte Carlo test predicts by simulation the

outcomes of an uncertain event. It helps to decide with a degree of confidence. It also shows what could happen and how likely each outcome is.

Table 3: The number of male and female respondents to key study questions

Respondent gender	Non-local cattle ownership	Breed preferences	Important dairy cattle traits	Main advantages	Main disadvantages
Male	240	210	240	206	198
Female	17	134	17	127	116
Total	257	344	257	333	314

For economic analysis, NR and gross margins (GM) calculation were done at household information level basis as gathered during the assessments. While all benefits and earnings were taken into consideration in NR, GM only factored earnings and costs in cash, see below for more detail. Calculations for NR and GM was done at two levels namely, per household herd per year (phpa) and per cow per year (pcpa). All currency valuations were done in the local currency in Senegal-(CFA). However, in this study CFA was converted to USD using a conversion rate of 580 CFA per 1 USD.

NR_{phpa} and GM_{phpa} were calculated as below.

Equation 3: Calculation of net returns per herd per annum

$$NR_{phpa} = \left[I_{milk\ sale,phpa} + B_{milk\ consumed,phpa} + B_{milk\ given\ away,phpa} + I_{animal\ sale,phpa} + B_{animals\ gifted\ in,phpa} + B_{animals\ given\ away,phpa} + I_{other\ incomes,phpa}\right] - \left[OC_{milk\ given\ away,phpa} + OC_{animals\ given\ away,phpa} + C_{animal\ purchase,phpa} + C_{feed,phpa} + C_{hired\ labour,phpa} + OC_{household\ labour,phpa} + C_{health,phpa} + C_{housing,phpa} + C_{reproduction,phpa} + C_{loan\ repayment,phpa} + C_{water,phpa} + C_{other\ expenses,phpa}\right]$$

Equation 4: Calculation of gross margins per herd per annum

$$GM_{phpa} = \left[I_{milk\ sale,phpa} + I_{animal\ sale,phpa} + I_{other\ incomes,phpa}\right] - \left[C_{animal\ purchase,phpa} + C_{feed,phpa} + C_{hired\ labour,phpa} + C_{health,phpa} + C_{housing,phpa} + C_{reproduction,phpa} + C_{loan\ repayment,phpa} + C_{water,phpa} + C_{other\ expenses,phpa}\right]$$

The selling of milk and milk products ($I_{milk\ sale}$), the selling of animals ($I_{animal\ sale}$), and other income ($I_{other\ incomes}$) were included in the income components (I). Animals inherited by the household as well as those given to the household as dowry ($B_{animals\ gifted\ in}$) and those given out for ceremonies, as dowry payment or as inheritance, ($B_{animals\ given\ away}$), milk taken by members of the household ($B_{milk\ consumed}$), and milk gifted out to others for consumption ($B_{milk\ given\ away}$) were all included in the benefit component (B).

The expenditures related to buying the animals ($C_{animal\ purchase}$), feeding them (C_{feed}), hiring labour ($C_{hired\ labour}$), giving them health-care (C_{health}), housing them ($C_{housing}$), paying for cows' reproduction activities ($C_{reproduction}$), paying back debts related to the domestic dairy cattle operation ($C_{loan\ repayment}$), watering animals (C_{water}), and any other costs ($C_{other\ expenses}$) are included in the cash cost components (C).

Other expenses (OC) included home labour ($OC_{household\text{-}labour}$), free milk given to other households ($OC_{milk\ given\ away}$), and free animals given to other households ($OC_{animals\ given\ away}$). Take note that giving away milk and animals were taken both as a benefit and a cost, with the gain being because they are farm produce and the cost being because household members do not use them.

NR_{pcpa} was computed as NR_{phpa} divided by herd size in cow years (identically for GM_{pcpa}). One cow year was taken as a cow being in the herd for a whole year (for example, two cows in the herd for six months each could be equal to one cow year).

The first computation of the various components was done for the specified monitoring period for each household herd and ranged between 481 and 565 days. After then, the values are transformed to years.

3.5 Comparisons of main breed types and net returns

Based on their NR_{pcpa} and the primary breed type they raised, the households were classified in order to assess economic performance amongst them. Using NR_{pcpa}, households were divided into roughly five equal units known as groups 1 to 5, with group 1 having the least NR and group 5 having the highest. Households were divided into groups according to the dominant breed type they raised. Note that most homes kept a mix of breed types, although with a dominant type. The means of the groups were compared using a One-way Analysis of Variance (ANOVA) with a significance threshold (alpha) of 0.05. To further evaluate mean differences in cases where there was a significant difference, the post hoc approach-Tukey's Honestly Significant Difference (HSD) was utilized, with a family-wise error level of 0.05.

3.6 Breed-type assignment

On the basis of farmer recall, cattle information collected in the baseline survey were categorized into 3 main groups (local, cross and exotic) to enable the analysis of trait and breed preferences. For economic analysis, genomic information or farmer recall for animals not genotyped elaborated in Marshall *et al.,* (2020) was used to assign breed-types. In this study, the breed-types assigned were; High *Bos taurus* (HBT); Indigenous Zebu and *Bos taurus* cross (IZ x BT); Indigenous Zebu and Guzerat cross (IZ x GZ) and indigenous Zebu (IZ). Note that within each group there was a range in the mix of breed type. Zebu Maure and Zebu Gobra were the most common Zebu breeds while Holstein Friesian and Montbeliarde were the predominant *Bos Taurus* cattle breeds, the latter two, both bred for their high milk production. As regards the Guzerat breed, it is a tropical breed developed from the Brasilian Crioulo cattle of European origin and the Indian Krankej cattle (Peixoto *et al.,* 2010).

For breed assignment based on farmer recall, the farmers were asked to name the breeds of each of their animals' grandparents (i.e., sire of sire, dam of sire, sire of dam, and dam of dam). These data were then used to determine the proportions of recent taurine (RT), ancient taurine (AT), recent zebu (RZ) and zebu (AZ); and the animals were then allocated to breed groups, Table 4. Using the Bovine 50K SNP chip (Illumina Inc., San Diego, CA), 624 female animals were genotyped for the genomic assignment. These animals were chosen because their lactation records were the most informative. Bayesian modelling analysis using reference genotype data was used to determine the level of admixtures of the test genotypes and therefore assign them the appropriate breed type. This enabled the estimation he proportions of recent taurine (RT), ancient taurine (AT), recent zebu (RZ), zebu (AZ) and ancient (indigenous) for each animal were derived based on the admixture result. Subsequently, each animal was put into a breed group, as shown in (Marshall *et al.*, 2020), Table 4.

Table 4: Guidelines for classifying animals into breeds types based on genomic data or ancestry data provided by farmer recall

		Breed type[1]		
	Indigenous Zebu (IZ)	IZ x Guzerat	IZ x *Bos taurus*	IZ x *Bos taurus*
According to ratios	Genotype 0.88-0.99 AZ	0.39-0.86AZ 0.13-0.61RZ	0.38-0.84AZ 0.13-0.61RT	0.00-0.36AZ 0.63-0.98RT
	Recall 1.00AZ	0.50-0.75AZ 0.25-0.50RZ	0.50-0.75AZ 0.25-0.50RT	0.00-0.25AZ 0.75-1.00RT

[1]RZ is for recently introduced zebu, RT for recently introduced *B. taurus*, and AZ stands for old (indigenous) zebu. Zebu Gobra and Zebu Maure dominate the AZ and RZ breeds, respectively, while Holstein Friesian and Montbéliarde dominate the RT breeds.

For instance, cattle that were 88% or more IZ based on their genotype for breed composition were assigned to the IZ group. Similarly, cattle whose proportion of IZ from the genotype analysis ranged between 39% and 86% were assigned to the IZ x GZ Marshall *et al.*, (2020) for other specific examples.

3.7 Drivers of net returns

Multi-variable regression analysis was used to identify if there were other factors apart from those included in the *NR* analysis that were influencing NR_{pcpa} and NR_{phpa} levels. The whole model's independent variables are listed in Table 5. Due to only a few of households having a female household head, the list did not include the household head's gender as overall, only 7 were female headed. Using R Core Team (2021) and the MASS module (Venables and Ripley, 1999) iterative regression with reverse exclusion relying on Akaike's Information Criterion (AIC) was used to obtain the final (shrunk) models.

Table 5: Variables in the complete model for the regression analysis of net returns

Independent variable	**Class**	**Description[1]**
Main breed-type kept	Discrete	5: IZ (41), IZ x GZ (22), IZ x BT (35), HBT (9), MX (6)
head Herd size in cow years	Continuous	12.5 (9.9)
Artificial insemination uses 5 years prior to the survey	Discrete	2: yes (94), no (36)
Dairy cattle record keeping (recall and written)	Discrete	2: yes (80), no (33)
Dominant ethnic group of household members	Discrete	2: Wolof (91), Fulani (22)
Primary livelihood source	Discrete	4: dairy cattle production (26), crop production (32), non-agricultural business (39), agricultural business (16)
The mean household income per year, where respondents selected from income ranges	Discrete	2:720-1440 USD (33), 1440-2880 USD (80)
Main means of selling milk	Discrete	2: market (46), individual customers (83)
Land size used for dairy, hectares	Continuous	1.6 (3.4)
Dairy cattle farming information source	Discrete	2: veterinarian (37) other farmers (76),
Number of household members (adults and children)	Continuous	19 (9.6)
Importance of dairy cattle keeping to the household in comparison to ten years year earlier	Discrete	3: more important (79), same importance (16), less important (34)
Number members in household (>18 years)	Continuous	7 (4.3)
Household head highest level of education	Discrete	4: informal (18), basic koranic (61), primary (13), post-primary (21)
Site	Discrete	2: Thies (56), Diourbel (57)

[1]USD = United States dollars [2]IZ =Indigenous Zebu; IZ x BT =Indigenous Zebu and *Bos taurus* cross; IZ x GZ= Indigenous Zebu and Guzerat cross; HBT =High *Bos taurus*; MX= Mixed [3]For discrete variables given is the number of levels, their names and, in brackets, numbers within each level. For continuous variables given is the mean and, in brackets, standard deviation.

CHAPTER FOUR: RESULTS

4.1 Objective 1: Breed and trait preferences

4.1.1 Factors associated with use of indigenous cattle breeds in Senegal

The majority of households (82.1%) reported having used a cross-breed (local x exotic) or exotic breed, whilst the remainder of households (17.9%) had only used local breeds. In this study, most households (79.2%) that had used a non-local breed type used them for the first time between 2004 and 2013. For the households that had used a non-local breed type (82.1%), the decision to use a non-local breed was made by a male household member in the majority (94.8%) of households. This was driven by own initiative, following a recommendation from another farmer, recommendation from a veterinarian or animal health practitioner and Non-Governmental Organization (NGO) staff for 38.4%, 36.05, 24.6% and 0.9% of the households respectively. About half (49.8%) of the households that had used a non-local breed type acquired it for the first time by upgrading from a local breed through AI Service. For the 17.9% of the households that had not used a non-local breed type, the main reason given by 63% of the respondents was that they could not access them. Most of the respondents (82.6%) that had not used a non-local breed type had plans to use them within next 1 to 3 years indicating that that dairy cattle keeping patterns in future may be different, Table 6.

Table 6: Percentages of various factors associated with use of non-indigenous cattle breeds in Senegal

Factor	Percentage
Use of a non-indigenous cattle breed	82.1(Yes), 17.9(No)
When the household first used a non-indigenous breed type	79.2(Between 2003 and 2013), 20.8(Before 2003)
Decision maker for the household that used a non-local cattle breed	94.8(Male), 5.2 (Female)
Motivation behind using a non-local breed	38.4(farmer), 36.05(veterinarian), 24.6(Other animal health practitioner), 0.9(NGO staff)
Mode of acquisition of the non-local cattle breed for households that had used it	49.8(Artificial insemination), 50.2(Natural mating)
Reason for not using a non-local breed for the 17.9% who had not used them	63(Unable to access), 27(Unable to afford)
Future plans to use a non-local breed by the 17.9% that had not used it	82.6(Yes), 17.4(No).

4.1.2 Breed preferences

There was a significant difference (p=0.00) in cattle breed preference among smallholder dairy cattle farming households. For all households, cross breed cattle with the highest standardized residual (std.res) of 10.87 were preferred more than either local or exotic cattle breed types, Table 7.

Table 7: Standardized residuals for household cattle breed type preference levels

Cattle breed	Preference level			
	High	**Moderate**	**Low**	**Indifferent**
Local	-9.85	6.48	6.18	-1.72
Cross	10.87	-3.57	-8.89	-3.38
Exotic	-1.31	-3.54	3.37	6.27
X^2	**202.63**			
p. value	**0.00***			

The greater the standardized residual, the higher the preference or non-preference for that preference level. *= Statistically significant at $p \leq 0.05$. X^2= Chi Square.

Disaggregated by gender, there was a significant difference (p=0.00) between breed preference by male and female respondents. Most male (71.9%) and female respondents (64.2%) had high preference for crosses compared to exotic and local breeds, Table 8. This is also shown by the

greater std. residuals for male respondents (9.89) and females (5.00) concerning crossbreeds in Table 9.

Table 8: Percentages of responses for breed preference disaggregated by gender

Gender	Breed	High	Moderate	Low	Indifferent
Male	Local	19.0	46.2	28.6	2.4
	Cross	71.9	25.2	1.0	1.0
	Exotic	22.9	14.8	11.0	2.9
Female	Local	35.1	43.3	12.7	1.5
	Cross	64.2	28.4	1.5	0.7
	Exotic	17.2	4.5	10.4	9.7

Table 9: Standardized residuals for cattle breed type preference levels by gender

		Preference level					
Gender	**Breed**	**High**	**Moderate**	**Low**	**Indifferent**	**X^2**	**p-value**
	Local	-9.61	4.99	6.53	-0.04		
	Cross	9.89	-3.70	-7.78	-1.85		
Male	Exotic	-0.40	-1.53	1.54	2.27	137.96	0.00*
	Local	-3.72	4.15	1.38	-2.34		
	Cross	5.00	-1.03	-4.36	-2.93		
Female	Exotic	-1.61	-4.00	3.81	6.70	92.28	0.00*

The greater the standardized residual, the higher the preference or non-preference for that preference level. *= Statistically significant at $p \leq 0.05$. X^2= Chi Square

4.1.2.1 Main advantages and disadvantages for cattle breeds kept

Male and female respondents were asked to give the main advantages, and disadvantages, of the breed-types they were familiar with. Table 10 shows the number of counts of responses disaggregated by gender for the cattle breed advantages and disadvantages.

Table 10: Number respondents (covering both breed advantages and breed disadvantages) disaggregated by gender

	Advantages			Disadvantages		
Breed type	Male	Female	Combined	Male	Female	Combined
Local	147	92	239	158	90	248
Cross	199	121	320	149	89	238
Exotic	84	29	113	96	46	142

Across all households there was a significant difference (p=0.00) among the main breed advantages for local, cross and exotic breed types. The main advantages for the local breed of cattle were: good adaption to the local conditions and low feed intake with standard residuals of 14.06 and 9.98 respectively. In contrast the main advantage of both the crossbreed and exotic dairy cattle was high milk yield (9.53 and 6.17 std.res). For cross breeds the second main advantage was good weight and conformity of the animal (6.30 std.res) while for exotic cattle breed, it was fast growth rate (4.63 std res), Table 11. The specific percentages of households per cattle breed trait advantage are shown in Table 12 under column 'C'.

Table 11: Standardized residuals for household cattle breed type main advantages

Advantages	**Local**	**Cross**	**Exotic**
Well adapted to local conditions	14.06	-8.37	-6.33
Low feed intake	9.98	-6.99	-3.09
Easy to manage	9.00	-6.71	-2.26
Good disease resistance	7.68	-4.93	-2.98
Good milk quality	5.50	-2.94	-2.91
Good walking ability	4.13	-2.17	-2.23
Low calf mortality	0.32	0.22	-0.70
Adequate conformation of the udder	-0.69	0.98	-0.45
Good reproductive rates	-1.43	-0.62	2.60
Nice coat colour	-2.32	1.18	1.31
High sale value of calves	-3.23	1.18	2.45
Good weight and conformity of the animal	-6.17	6.30	-0.73
Fast growth rate	-8.83	4.76	4.63
High milk yield	-15.18	9.53	6.17
X^2		**745.88**	
p-value		**0.00***	

The greater the standardized residual, the more advantageous the trait for that cattle breed type. *= Statistically significant at $p \leq 0.05$. X^2= Chi Square

Table 12: Percentage of respondents naming the main breed type advantages

	Local			Cross			Exotic		
Main advantage	M	F	C	M	F	C	M	F	C
Well adapted to local conditions	60.5	47.8	55.6	13.6	7.4	11.3	0.0	0.0	3.5
Good disease resistance	31.3	12.0	23.8	8.5	2.5	6.3	4.8	0.0	3.5
Easy to manage	30.6	21.7	30.1	6.0	1.7	4.4	6.0	6.9	6.2
Low feed intake	17.7	20.7	18.8	0.0	0.0	1.9	0.0	0	0.9
Good milk quality	16.3	16.3	16.3	5.5	7.4	6.3	1.2	3.4	1.8
Good walking ability	6.1	8.7	4.2	3.5	0.0	2.2	0.0	0.0	0.0
Low calf mortality	2.7	0.0	1.7	3.0	0.0	0.0	1.2	0.0	0.0
Fast growth rate	2.0	0.0	1.3	39.2	27.3	34.7	45.2	34.5	42.5
High milk yield	2.0	6.5	3.8	87.9	82.6	85.9	94	82.8	91.2
High sale value of calves	2.0	0.0	1.3	9.5	3.3	7.2	13.1	3.4	10.6
Nice coat colour	1.4	0.0	0.8	3.5	5.8	4.4	3.6	10.3	5.3
Good reproductive rates	0.7	1.1	0.8	2.0	1.7	1.9	7.1	0	5.3
Good weight and conformity	0.7	3.3	1.7	31.2	14.9	25.0	11.9	13.8	8.8
Adequate udder conformation	0.0	0.0	0.0	0.0	0.8	0.3	0.0	0.0	0.0
X^2	16.29			17.43			5.16		
p-value	0.04*			0.04*			0.51		

M=Male, F=Female, C=Combined, X^2= Chi Square. *= Statistically significant at $p \leq 0.05$. Means distributions between male and female respondents were statistically significantly different for that breed group.

Similarly, across all households, there was a significant difference (p=0.00) among the main breed disadvantages for local, cross and exotic breed types. The main disadvantages for the local breed of cattle were: low milk yield and inadequate weight and conformity of the animals with standard residuals of 20.82 and 6.62 respectively. In contrast the main disadvantages of crossbreed dairy cattle were high feed intake and poor disease resistance (9.63 and 3.90 std.res). For exotic dairy cattle breeds the main disadvantages were poor adaption to local conditions and difficult management with 5.91 and 2.83 std res. Respectively, Table 13. The specific percentages of households per cattle breed trait disadvantage are shown in Table 14 under column ‘C’.

Table 13: Standardized residuals for household cattle breed type main disadvantages

Disadvantages	**Local**	**Cross**	**Exotic**
Low milk yield	20.82	-12.82	-8.88
Inadequate weight and conformity	6.62	-4.04	-2.87
Poor growth rate	5.10	-3.11	-2.21
Low sale value of calves	3.24	-2.40	-0.92
Poor reproductive rates	2.14	-0.39	-1.97
Poor milk quality	1.32	0.10	-1.60
Inadequate shape and size of the udder	-0.71	-0.80	1.7
High calf mortality	-0.77	-0.80	1.77
Poor walking ability	-2.93	1.70	1.37
Difficult to manage	-3.57	1.05	2.83
Poor disease resistance	-6.20	3.90	2.55
Poor adaption to local conditions	-8.26	2.99	5.91
High feed intake	-11.94	9.63	2.50
X^2		**643.42**	
p-value		**0.00***	

The greater the standardized residual, the more advantageous the trait for that cattle breed type. *= Statistically significant at $p \leq 0.05$. X^2= Chi Square

Table 14: Percentage of respondents naming the main breed disadvantages

	Local			Cross			Exotic		
Main disadvantage	M	F	C	M	F	C	M	F	C
Low milk yield	84.2	85.6	84.7	1.3	4.5	2.5	3.1	4.3	3.5
Inadequate weight and conformity	11.4	7.8	10.1	0.0	0.0	0.0	0.0	0.0	0.0
Poor growth rate	8.9	1.1	7.3	0.0	0.0	0.0	0.0	0.0	0.0
High feed intake	4.4	2.2	3.2	59.1	66.3	61.8	54.2	34.8	47.9
Low sale value of calves	4.4	1.1	3.2	0.0	0.0	0.0	1.0	0.0	0.7
Poor adaption to local conditions	3.8	1.1	2.8	33.6	19.1	28.2	45.8	32.6	41.5
Difficult to manage	3.2	3.3	3.2	10.7	10.1	10.5	12.5	21.7	15.5
Poor disease resistance	3.2	1.1	2.4	24.2	16.9	21.4	22.9	19.6	21.8
Poor milk quality	3.2	3.3	3.2	2.0	3.4	2.5	1.0	0.0	0.7
Poor reproductive rates	3.2	3.3	2.8	2.0	1.1	1.7	0.0	0.0	0.0
Poor walking ability	1.3	2.2	0.0	6.7	7.9	8.0	7.3	8.7	7.7
Inadequate udder shape and size	0.6	1.1	0.8	1.3	0.0	0.8	2.1	4.3	2.8
High calf mortality	0.0	0.0	0.4	0.0	0.0	0.4	1.0	0.0	0.0
X^2	11.11			8.72			5.69		
p-value	0.44			0.28			0.47		

[1]M=Male, F=Female, C=Combined, X^2= Chi Square. *= Statistically significant at $p \leq 0.05$. Means distributions between male and female respondents were statistically significantly different for that breed group.

The distribution of named cattle breed advantages was significantly different between male and female respondents for local (p-value=0.04) and cross-breed cattle p-value=0.04), but not

exotic cattle (p-value=0.05) (Table 12). However, the distribution of named cattle breed disadvantages was not significantly different between male and female respondents for all the 3 cattle breed types (p-value>0.05) (Table 14). More male respondents named adaption to local conditions (12.7% more men than women), good disease resistance (19.3%) and ease of management (8.9%) as the main advantages for keeping local breed of cattle whilst more women than men named low feed intake (3.0%) and good walking ability (2.6%). On the other hand, for cross breeds, more men named good weight and conformity (16.3%), faster growth rate (11.9%) and high milk yield (5.3%) while nice coat colour (2.3%) and good milk quality (1.7%) were named by more women.

4.1.3 Important dairy cattle traits

The traits most commonly named by all respondents (both male and female) as important were milk yield (93.1% of respondents), live weight or size of the animal (74.2%), disease resistance and feed intake (both at 73.7%), and milk quality (70.5%). Traits that were named as important by fewest respondents were, calf mortality, coat colour and udder conformation (34.6%, 27.6% and 25.8% of the respondents) respectively. Considering preference ranking for the important traits only, most farmers assigned the highest rank (mode of 1) to milk yield, followed by live weight (mode of 2), sale value of calves and milk quality, the latter two traits with a mode of 3 each. Although coat colour was named important by fewest farmers, it had a preference rank mode of 4 with a range of 1-12 indicating that some respondents considered it the most important trait above other vital traits such as disease resistance and feed intake. Traits ranked by all respondents as least important were calf mortality and udder size or conformation (rank 10 and 12 respectively). It is notable that almost all-important cattle traits save for sale value of calves and calf mortality were assigned preference rank 1 by some farmers See Table 15.

Table 15: Traits by level of importance on dairy farms

	% of respondents	Preference rank	
Trait	Trait is important	Mode[1]	Range
Milk yield	93.1	1	1-11
Live weight or size of animal	74.2	2	1-12
Disease resistance	73.7	5	1-11
Feed intake	73.7	6	1-12
Adaptability to local conditions	71.4	4	1-14
Milk quality (% fats)	70.5	3	1-10
Easy to manage or handle	67.7	7	1-12
Reproductive qualities	66.8	7	1-12
Sale value of calves	59.0	3	2-12
Calf mortality	34.6	10	2-12
Coat colour	27.6	4	1-12
Udder conformation or size	25.8	12	1-12

[1]The smaller the mode of the preference rank, the more the trait is preferred.[2]Respondents were heads of households (240 men and 17 women)

4.2 Objective 2: Profitability and economic analysis of dairy cattle keeping households

4.2.1 Dairy cattle keeping households' characteristics

85.8% of families named dairy production as one of their three leading income streams. Additionally, agricultural businesses accounted for 70.8 % of families' forms of income, followed by non-agricultural businesses (54.0 %) and crop cultivation (53.1%). A majority (70.8%) of the households reported their household income per annum to be between 1440 USD and 2880 USD. Other respondents said it was between 720 and 1440 USD annually. Wolof (80.5%) and Fulani (19.5%) were the two largest ethnic groupings that households identified with. All household members, including children, were counted, and the average number of households was 19 (with a standard deviation of 9.6). Primary education (11.5%), post-primary education (18.6%), informal education (16%), and elementary education (54.0%) were the levels of education most frequently reported by household heads.

By percentage 19.5%, 31.0% and 36.3% of the households kept, IZ x GZ, IZ x BT and IZ as their primary breed-type respectively. HBT was kept by only 8.0% of the households. The main milk buyers from the households were individuals (73.5%) while the market was where the rest

sold their milk. Grazing and supplementary (purchased) feeding was practised by most households (79.6%) while the remaining families only used commercial feeds (15.0%) or just let their animals graze (5.3%). Ground nut cake and concentrates were primary auxiliary feeds kinds utilized. Crop residues including cassava (as rinds and stalks), groundnut (as haulms) and maize (as stover) were also used as animal feed. Grazing was permitted without fee on community land. Regarding techniques of reproduction in cattle, natural mating, both AI and natural mating, and AI solitarily was used by 70.8%, 22.1% and 7.1% of the households respectively. Most of the households (71%) kept cattle records (whether in written or by recall). Other farmers were the main source of information on dairy cattle keeping to a majority of the households (67.3%). Table 5 provides additional significant characteristics of the households that raised dairy cattle.

4.2.2 Net returns and gross margins from cattle keeping, across all households

Results from the NR analyses are given in Fig. 4 and Table 16. The mean and (in brackets) standard deviation for NR_{pcpa} and NR_{phpa} was 21.7 (202.9) and 106.1 (1740.3) USD respectively. For approximately half (52.2 %) of the dairy cow raising households, there was a positive NR, albeit a tiny one. The most important source of income components for both NR_{pcpa} and NR_{phpa} were milk sale followed by animal sale, whereas the most important expense component was livestock feed trailed by livestock purchase (Table 16). Since the value of benefits and non-cash expenses was modest, as indicated in Table 16, NR and GM analyses produced identical conclusions. Due to the significant correlations between NR and GM—0.99 for phpa and 0.98 for pcpa—the data that follow are only reported for NR analysis.

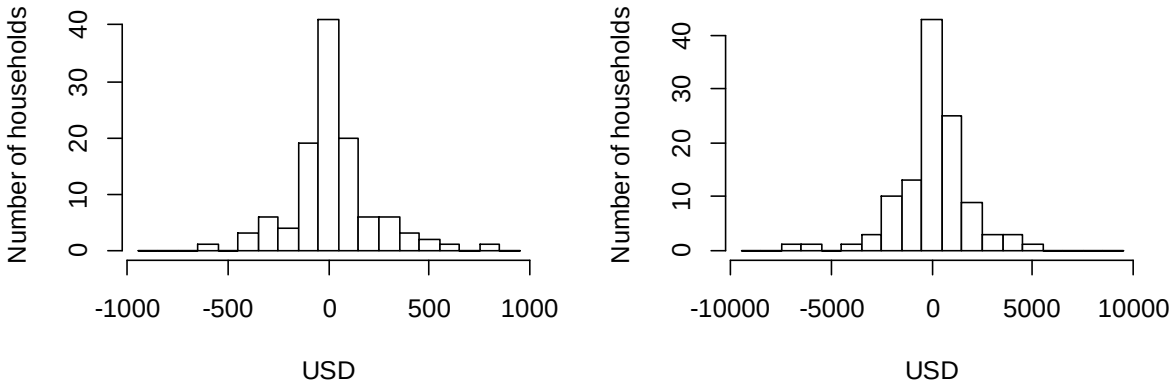


Figure 4: Distributions of net returns per cow annually (left) and net returns per herd annually (right), for all households.

Table 16: Analysis of net returns and gross margins in United States Dollars

Variable	NR	GM	Per cow per annum				Per herd per annum			
			Mean	SD	Min	Max	Mean	SD	Min	Max
Income and benefit components										
Milk sale	✓	✓	172.2	178.6	1.4	910.7	1865.0	2794.5	12.5	20962.9
Animal sale	✓	✓	120.3	192.5	0.0	1038.1	1002.8	1411.8	0.0	7896.1
Milk consumed	✓		19.5	18.7	0.0	85.7	182.2	173.3	0.0	817.5
Animals gifted in	✓		4.8	32.5	0.0	260.0	27.2	143.6	0.0	993.0
Animals given away	✓		3.1	14.9	0.0	131.9	27.5	124.7	0.0	1062.6
Milk given away	✓		2.5	6.6	0.0	39.2	30.0	85.5	0.0	713.1
Other incomes	✓	✓	0.4	4.6	0.0	48.5	3.1	31.1	0.0	329.9
Total income NR			**322.7**	**328.0**	**13.3**	**1562.6**	**3137.8**	**3935.4**	**160.9**	**30817.2**
Total income GM			**292.9**	**302.5**	**13.3**	**1415.6**	**2870.8**	**3705.5**	**110.5**	**28342.3**
Cost components										
Feed	✓	✓	146.4	194.3	0.0	1174.1	1393.1	2830.7	0.0	27026.5
Animal purchase	✓	✓	62.8	119.7	0.0	679.6	831.1	1936.3	0.0	12866.4
Hired labour	✓	✓	37.2	26.4	0.0	132.7	328.7	186.4	0.0	1064.4
Household labour	✓		20.9	21.1	0.0	93.3	167.8	153.9	0.0	833.9
Housing	✓	✓	11.3	19.9	0.0	129.0	102.0	154.6	0.0	798.8
Reproduction	✓	✓	6.6	15.8	0.0	104.4	45.0	97.4	0.0	574.3
Health	✓	✓	4.5	5.0	0.0	23.4	46.6	54.5	0.0	273.5
Water	✓	✓	4.3	5.6	0.0	27.8	39.4	51.4	0.0	218.5
Animals given away	✓		3.1	14.9	0.0	131.9	27.5	124.7	0.0	1062.6
Milk given away	✓		2.5	6.6	0.0	39.2	30.0	85.5	0.0	713.1
Loan repayment	✓	✓	1.1	6.6	0.0	54.7	14.8	99.4	0.0	921.1
Other expenses	✓	✓	0.5	2.0	0.0	18.0	5.7	33.1	0.0	330.0
Total cost NR			**301.1**	**287.7**	**16.1**	**1612.3**	**3031.8**	**4267.5**	**166.0**	**37113.3**
Total cost GM			**274.6**	**278.7**	**4.4**	**1528.7**	**2806.4**	**4168.0**	**30.4**	**35188.7**
NR			**21.7**	**202.9**	**-639.1**	**807.4**	**106.1**	**1740.3**	**-6590.1**	**5416.0**
GM			**18.3**	**195.3**	**-602.6**	**806.0**	**64.4**	**1741.2**	**-6846.4**	**5158.3**

NR= Net Returns; GM= Gross Margins; SD=Standard Deviation; Max=Maximum; Min=Minimum

For the households that raise dairy cattle, NRpcpa and NRphpa analyses found strong correlations between overall income and overall cost of 0.79 and 0.91, respectively. Costs tended to be higher for households with the highest incomes (Fig. 5). It is noteworthy that the majority of homes were clustered around areas with poor total income and low total expenses. Additionally, several outlying households (off the best fit line) had both the greatest and poorest NR; (income greater than expenses) and (costs greater than income) respectively. Below, these households are discussed in greater detail.

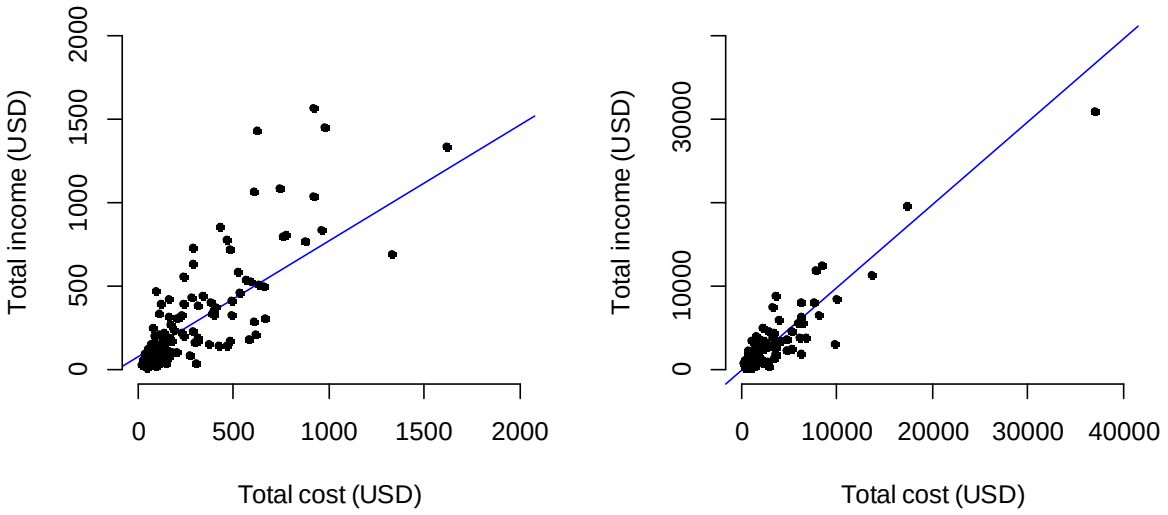


Figure 5: Total income versus total cost per cow annually (left) and per herd annually (right) for net returns (NR) analysis

In the three outlier households with the greatest NRpcpa, high animal sales in 2 households and a combination of high animal and milk sales in 1 household appear to be the primary drivers of NR. In contrast, one of the three homes with the lowest NRpcpa had a low rate of animal sales, another had a high rate of animal purchases, and the third had a mix of both.

4.2.3 Dairy cattle keeping households grouped based on NR_{pcpa}

To further explore the income and expenditure contributions to various levels of NR, households were classified depending on NR_{pcpa} rating (5 groups, group 1 with the least mean NRpcpa and group 5 with the greatest mean NR_{pcpa}). See Table 17 and Fig. 6. Interestingly, the total revenue and total expenditure did not grow linearly from group 1 to group 5, but the NR

did. Instead, on plotting, their layout displayed a form of a 'U'(Fig.6). While group 5, which had the highest NR_{pcpa} mean of 315.5 USD, had the greatest income and second-highest cost, group 1, which had the lowest mean NR_{pcpa} of -237.1 USD, had the highest costs (across the groups). Depending on which groups it was being compared to, group 5's total revenue was statistically considerably greater due to increased milk sales, milk consumption, and/or animal sales. See Table 17. For groups 1 and 5, total cost was statistically considerably greater in compared to the other groups. This was due to increased expenditures for purchasing animals, feeding them, and/or paying workers (again, based on what group it is being contrasted with). Additionally, it is noteworthy that group 5 households mostly raised the IZ x BT breed type, and that group 3 had the least overall costs and total income with an average NR pcpa of 11.2 USD.

Table 17: Household groups based on net return per cow per annum (NR_{pcpa}) and herd structure (group 1 has the least NR_{pcpa} and group 5 the greatest). The mean and standard deviation (in brackets) of the NR components are presented in US dollars.

	Group 1	Group 2	Group 3	Group 4	Group 5	p-value
Net return analysis						
Income and benefit components						
Milk sale	214.4(202.6)^{a,b}	113.0(106.7)^{b}	91.3(149.9)^{b}	122.6(106.9)^{b}	327.9(201.8)^{a}	0.00*
Animal sale	93.4(153.1)^{b}	71.3(102.1)^{b}	36.6(33.4)^{b}	98.5(98.6)^{b}	308.7(321.3)^{a}	0.00*
Milk consumed	19.9(20.2)^{a,b}	13.9(17.3)^{b}	12.7(14.5)^{b}	21.2(18.5)^{a,b}	30.6(18.5)^{a}	0.00*
Animals given away	5.0(13.3)	0.0(0.0)	1.2(4.6)	2.5(11.8)	7.0(28.3)	0.52
Milk given away	4.3(10.3)	0.8(2.0)	3.0(8.3)	2.5(4.2)	1.9(4.6)	0.55
Animals gifted in	0.0(0.0)	1.0(4.7)	1.0(4.7)	0.2(1.0)	22.2(72.0)	0.09
Other incomes	0.0(0.0)	0.0(0.0)	2.1(10.1)	0.1(0.4)	0.0(0.0)	0.43
Total income	**336.9(321.2)^{b}**	**200.0(177.4)^{b}**	**147.9(164.3)^{b}**	**247.6(174.7)^{b}**	**698.2(416.3)^{a}**	**0.00***
Cost components						
Feed	306.8(246.7)^{a}	99.8(116.2)^{b}	56.0(128.2)^{b}	66.7(110.6)^{b}	212.3(215.5)^{a}	0.00*
Animal purchase	143.0(164.9)^{a}	59.0(92.8)^{a,b}	21.7(51.8)^{b}	35.5(64.3)^{b}	58.0(153.8)^{a,b}	0.00*
Hired labour	45.3(26.1)^{a}	40.6(27.2)^{a,b}	23.7(21.0)^{b}	34.9(25.6)^{a,b}	42.0(28.3) ^{a,b}	0.05*
Household labour	19.6(20.0)	23.6(24.0)	17.8(16.4)	20.4(19.4)	23.1(26.0)	0.88
Reproduction	17.0(26.7)^{a}	5.0(10.0)^{a}	0.8(2.5)^{b}	0.8(2.3)^{b}	10.0(17.2)^{a}	0.00*
Housing	15.4(17.9)	9.8(16.5)	3.8(6.7)	10.8(21.8)	17.3(29.2)	0.18
Health	7.1(5.4)^{a}	2.7(2.7)^{b}	2.5(2.8)^{b}	2.2(2.7)^{b}	8.3(6.7)^{a}	0.00*
Water	6.5(5.7)	5.7(6.9)	3.8(6.0)	2.9(3.9)	2.5(4.3)	0.07
Animals given away	5.0(13.3)	0.0(0.0)	1.2(4.6)	2.5(11.8)	7.0(28.3)	0.52
Milk given away	4.3(10.3)	0.8(2.0)	3.0(8.3)	2.5(4.2)	1.9(4.6)	0.55
Loan repayment	2.9(9.5)	0.1(0.6)	2.4(11.4)	0.2(0.8)	0.1(0.5)	0.41
Other expenses	1.2(2.3)	0.1(0.2)	0.1(0.2)	0.9(3.7)	0.1(0.3)	0.17
Total cost	**574.1(358.3)^{a}**	**247.0(181.7)^{b}**	**136.7(159.8)^{b}**	**180.3(171.5)^{b}**	**382.7(294.9)^{a}**	**0.00***
Net returns	**-237.1(135.2)^{d}**	**-46.9(22.8)^{c}**	**11.2(14.5)^{b,c}**	**67.3(23.8)^{b}**	**315.5(178.3)^{a}**	**0.00***
Herd structure						
Herd size (cow years)	10.4(6.6)^{a,b}	12.3(10.1)^{a,b}	17.7(14.1)^{a}	12.6(8.6)^{a,b}	9.0(6.4)^{b}	**0.04***
Main breed-type	**Percentage of households per group**					
IZ	18.2	43.5	56.5	34.8	27.3	
IZ x GZ	22.7	13	26.1	21.7	13.6	
IZ x BT	31.8	39.1	13	30.4	40.9	
HBT	18.2	0	4.3	4.3	13.6	
MX	9.1	4.3	0	8.7	4.5	
N of households	**22**	**23**	**23**	**23**	**22**	

IZ=Indigenous Zebu; IZ x BT=Indigenous Zebu and Bos taurus cross; IZ x GZ=Indigenous Zebu and Guzerat cross; HBT=High Bos taurus; MX=Mixed; N=number

*= Statistically significant at $p \leq 0.05$. Means on the same row with different superscript letters are significantly different

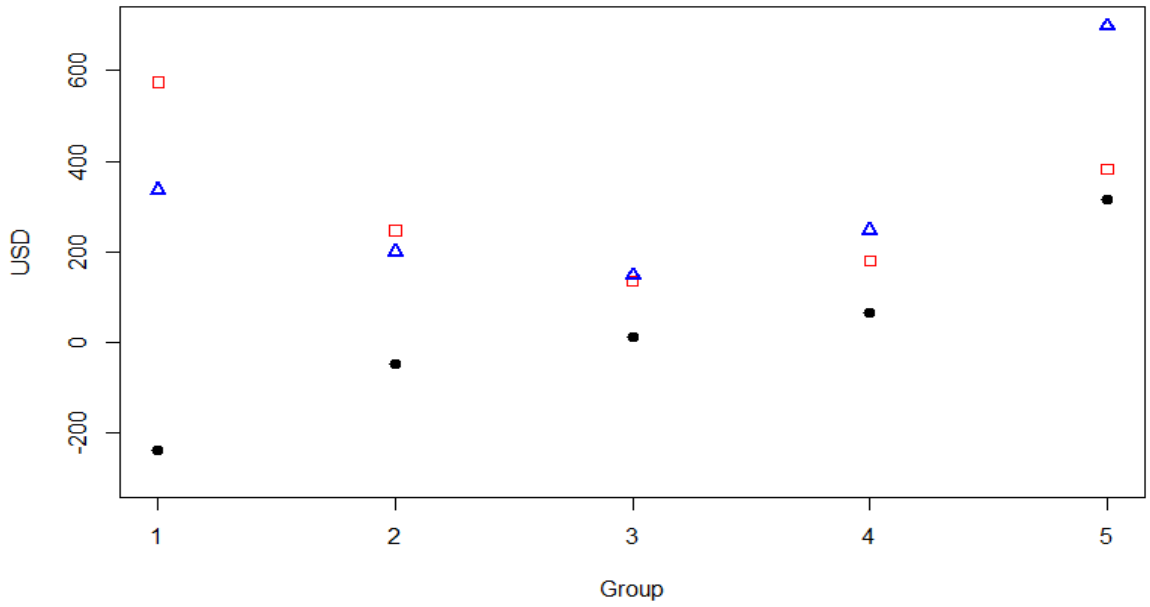


Figure 6: An illustration of the total revenue per cow per year (blue triangle), total cost per cow per year (red square), and net returns per cow per year (black circle) for groups of households ranked according to net returns per cow per year (with group 1 having the lowest net returns and group 5 the highest). United States Dollars, or USD

4.2.4 Dairy cattle keeping households grouped based on breed-type kept

To examine how breed type affects NR, households were divided into groups according to whether they raised IZ, IZ x GZ, IZ x BT, or HBT as their main breed type (Table 18). Each group had a different number of households, ranging from 9 for HBT to 41 for IZ. These results need to be taken carefully because the HBT group only included a small number of households. Due to the high range around the averages, there were no statistically considerable variations in NR_{pcpa} means for the different breed-groups. However, there were statistically significant differences in overall cost and income between the breed-groups. HBT and IZ x BT had their total income statistically signicantly higher compared to IZ x GZ and IZ. This difference was caused by differences in income from animal sale and milk sale (including milk taken and given away). It is noteworthy that HBT earned the most money from milk sales, trailed by IZ x BT, IZ x GZ, and IZ. HBT's total cost was statistically substantially greater than that of IZ x BT,

which in turn was more than that of IZ x GZ and IZ. HBT had the greatest feed expenses, trailed by IZ x BT, IZ x GZ, and IZ. The most expensive animal purchases were made by households that kept HBT and BT x IZ. See Table 18.

Table 18: An examination of households' annual net returns per cow, in US dollars, broken down by the main breed type kept (mean and standard deviation in brackets). Each group's number of households is also listed.

	IZ	IZ x GZ	IZ x BT	HBT	p-value
Income and benefit components					
Milk sale	81.0(83.1)^{c}	103.0(138.9)^{c}	245.9(149.7)^{b}	453.5(283.1)^{a}	0.00*
Animal sale	58.8(89.1)^{b}	92.0(102.8)^{a,b}	186.1(271.5)^{a}	165.1(246.8)^{a,b}	0.02*
Milk consumed	10.8(12.9)^{c}	16.3(15.2)^{b,c}	29.2(20.6)^{a}	25.1(16.8)^{a,b}	0.00*
Other incomes	1.2(7.6)	0.0(0.0)	0.1(0.3)	0.0(0.0)	0.68
Milk given away	0.8(2.1)^{b}	3.9(5.7)^{a,b}	2.1(6.7)^{b}	9.0(15.4)^{a}	0.01*
Animals gifted in	0.7(3.6)	0.0(0.0)	14.6(57.6)	0.0(0.0)	0.23
Animals given away	0.6(3.5)	3.9(10.4)	5.4(24.0)	5.1(15.4)	0.57
Total income	**153.8(141.4)^{b}**	**219.1(185.8)^{b}**	**483.3(363.8)^{a}**	**657.9(511.6)^{a}**	**0.00***
Cost components					
Feed	59.6(95.0)^{c}	83.7(94.5)^{c}	212.9(181.5)^{b}	399.9(389.3)^{a}	0.00*
Hired labour	25.9(21.8)^{b}	37.3(25.6)^{a,b}	44.7(25.6)^{a}	39.2(30.1)^{a,b}	0.01*
Animal purchase	25.1(50.6)^{c}	34.2(54.2)^{b,c}	95.6(127.6)^{a,b}	159.4(237.4)^{a}	0.00*
Household labour	20.6(22.1)	29.5(24.4)	18.1(18.9)	13.4(16.2)	0.16
Housing	4.6(8.3)^{b}	7.5(12.7)^{a,b}	16.3(24.3)^{a}	19.6(20.6)^{a,b}	0.01*
Water	2.7(3.1)^{b}	6.3(4.3)^{a,b}	3.5(6.6)^{a,b}	8.4(10.1)^{a}	0.01*
Health	2.6(2.2)^{b}	3.6(5.4)^{a,b}	6.5(5.3)^{a}	8.2(7.4)^{a}	0.00*
Reproduction	0.9(3.7)^{b}	4.0(7.8)^{a,b}	12.4(22.6)^{a,b}	12.5(22.0)^{a}	0.06*
Other expenses	0.8(3.0)	0.1(0.3)	0.2(0.6)	0.3(0.4)	0.45
Milk given away	0.8(2.1)^{b}	3.9(5.7)^{a,b}	2.1(6.7)^{b}	9.0(15.4)^{a}	0.01*
Animals given away	0.6(3.5)	3.9(10.4)	5.4(24.0)	5.1(15.4)	0.57
Loan repayment	0.1(0.5)	0.0(0.1)	3.5(11.7)	0.3(0.8)	0.11
Total cost	**144.2(124.4)^{c}**	**213.9(165.9)^{c}**	**421.2(283.3)^{b}**	**675.2(466.8)^{a}**	**0.00***
Net returns	**9.6(119.8)**	**5.2(128.3)**	**62.1(286.7)**	**-17.4(272.4)**	**0.58**
N households	**41**	**22**	**35**	**9**	

IZ Indigenous Zebu; IZ *x BT* Indigenous Zebu and *Bos taurus* cross; *IZ x GZ* Indigenous Zebu and Guzerat cross; *HBT* High *Bos taurus; N* number; *= Statistically significant at $p \leq 0.05$. The means on the same row with different superscript letters are statistically significantly different.

4.2.5 Drivers of net returns in dairy cattle keeping households

To ascertain if any exogenous (not included in the economic analysis) social or other factors affected NRpcpa and NRphpa, regression analysis was performed. The best model across all households exhibited a coefficient of determination (R^2) of 0.120 for NRpcpa and an R^2 of 0.117 for NRphpa. (That is, the models only partially explained the variance in NR, which was to be expected given the sort of variables included.) Given the kind of components in the model, a low R^2 may be anticipated (i.e. external to those considered in the economic analysis).

The final models were as below:

Equation 5: Final model with exogenous factors affecting net returns per cow per annum

$$NR_{pcpa} = -39.0 + prior\ AI\ use\ (80.9\ if\ yes, 0\ if\ no) + milk\ buyer\ (101.5\ if\ market, 0\ if\ individual\ buyer) + site\ (-76.2\ if\ Thiès, 0\ if\ Diourbel)$$

Equation 6: Final model with exogenous factors affecting net returns per herd per annum

$$NR_{phpa} = -920 + prior\ AI\ use\ (783.4\ if\ yes, 0\ if\ no) + milk\ buyer\ (1168.6\ if market, 0\ if\ individual\ buyer)$$

The anticipated NR both for the pcpa and phpa of Senegalese smallholder dairy cow operations was increased by selling milk in the market (as opposed to individual purchasers) and previous use of AI. Thies households had a lower NR_{pcpa} than Diourbel households, hence site was retained in the final model for NR_{pcpa} (but not NR_{phpa}).

CHAPTER FIVE: DISCUSSION

5.1 Dairy cattle breeding practices

5.1.1 Use of non-local dairy cattle breed types

In this study the high percentage of use of non-local breed types is due to local cattle being purposely crossed with exotic breeds in Senegal (Marshall *et al.,* 2020; Ndiaye *et al.,* 2015). However, it is notable that households that kept different dairy cattle breed-types were purposefully selected to take part in this study hence this finding may best apply in the agro-pastoral production system in the region often known as the Peanut basin of Senegal. Other reasons for this finding include transhumance which is used traditionally to manage livestock after severe droughts in West African countries including Senegal (Ndiaye *et al.,* 2015). Senegal has funded several AI initiatives around the nation since 1995 and has gradually established laws and regulations for improvement and management of genetic enhancement efforts. Numerous dairy cattle producers in Senegal have benefited from free AI initiatives financed by the government, as seen by the rise in the use of private insemination outside of free campaigns(Diouf *et al.,* 2016; Marshall *et al.,* 2020; Ndiaye *et al.,* 2015). The largest government funded AI programme in Senegal (the Special Programme for AI-PSIA) operated from 2008-2014, (Diouf et al., 2016), this explains why most dairy cattle keeping households (79.2%) used a non-local breed type for the first time between 2003 and 2013.

The finding in this study that key decisions on use of non-local dairy cattle breed types in most households was made by male household member agrees with a finding by Yisehak (2008) in Ethiopia that men are largely the decision makers for livestock production choices and are in charge of general herd management. Further, in this study, the minimal AI's success rate in Senegal which has never reached 50% (Cabral, 2016) can explain the low AI use (less than half of the households) to upgrade their local dairy cattle breeds. Reasons for this include; animals

in too poor condition to conceive due to insufficient and poor quality feed, and inexperience of the AI service providers (Cabral, 2016).

5.1.2 Dairy cattle breed preferences

The breed and trait choices for dairy cattle in this study in Senegal are typical of the diverse objectives of livestock keepers and are in line with findings from previous studies in Kenya by (Bebe *et al.,* 2003; Mwacharo & Drucker, 2005). The finding from this study that there is an overall preference for cross breed cattle compared to either local cattle breeds or exotic cattle breeds (Table 8 and 9) is similar to findings from a study by (Kamuanga *et al.*, 1999) in various locations in West Africa and (Traoré *et al.,* 2017) in Southern Mali. (Lukuyu *et al.,* 2019) notes that in tropical Africa, Senegal included, cross breed cattle are preferred by smallholder dairy farmers because these farmers are interested in multiple traits such as high milk yield and good adaptation to local conditions.

The study by (Traoré *et al.,* 2017) further identified high milk yield and larger body sizes as the two main reasons for preferring cross breeds by farmers in Southern Mali of West Africa. This agrees with the finding of this study that smallholder dairy cattle keepers in Senegal prefer cross breed dairy cattle because of the high milk yield followed by fast growth rate, (Table 5). The finding that crossbreed cattle and exotic cattle were both named by over 80% of the farmers to have the advantage of high milk production (Table 12) is in line with the findings from a study by (Puppel *et al.*, 2018). In Puppel's study, crossbreeding Holstein Friesian cows with bulls from other dairy or mixed groups resulted in cross breed cows with the highest milk quality and quantity. To be able to increase producer income by improving lactation length, reducing calving interval, increasing the quantity of milk produced, and having cows calve at younger ages, crossbreeding exploits use of additive and non-additive allele gene effects (Osei-Amponsah et al., 2020). Thus, crossbreeding has been used as a strategy for enhanced milk production in many tropical nations to create crossbreds that are both more productive than the

native breeds and adapted to the environment (Ojango *et al.,* 2017; Kebede *et al.,* 2018 and Osei-Amponsah *et al.,* 2020).

This study identified high feed intake followed by poor adaption to local conditions as the main disadvantages for keeping cross breed cattle. Although the high feed intake can be explained in part by the high production demands (milk and meat) attached to the crossbreed, there is additional cost of keeping the crossbreeds under cut and carry feeding regime system where they must be fed with supplements and concentrates. This is unlike the local breeds which are grazed under the migratory pastoral system with minimal supplementation. As a result, the crossbreed production system is associated with significant labour needs to feed, clean, and manage intensively kept dairy cattle. This necessitates managerial skills as well as equipment such as feeding troughs, lighting systems, shelter separation, and disease management, all of which are additional tasks for smallholder farmers (Roschinsky *et al.,* 2015; Osei-Amponsah *et al.,* 2020).

In this study, local cattle were the second most preferred cattle breed by women unlike men (Table 8). That women had higher preference of local cattle can be explained by the main advantages they gave for keeping local cattle such as good milk quality, ease of management, and low feed intake. Good milk quality could be a preference for taste while ease of management and low feed intake could be associated with farm economics as low feed intake would save on costs associated with keeping the breed and ease of management could save on labour cost hence boosting farm profitability. Overall, the main reasons for preferring local cattle were good adaptability to local conditions such as good disease resistance and low feed intake (adaptive traits) and ease of management. (Table 12). As expected local breeds were named as having the best disease resistance advantage by most respondents while exotic breeds were named by most respondents as having the poorest disease resistance (Table 12). Apparently, livestock keepers tend to prefer local breeds when they consider disease tolerance

as important and assume they lose that value when they choose crosses, a loss that could be compensated for by higher returns due to the advantageous productive traits of cross breeds. This study's finding that low milk production was the main disadvantage for local cattle breeds agrees with the findings of (Quddus, 2017), who noted that average daily milk yield in Senegal has been reported to be about 1.9 L in a native tropical cow and 5.9 L in hybridized cows, with income levels from milk yields of crossbred cows being 3.2 times higher than local cows.

5.1.3 Dairy cattle trait preferences

In this study, livestock keepers ranked productive traits such as milk production, live weight and size of the animal; and sale value of calves (Table 15) as more important compared to adaptable traits such as disease resistance, adaptability to local conditions and feed intake. These results are consisted with results in a study by (Wurzinger *et al.,* 2006) where Ankole breed of cattle were ranked first for milk output and body size by cattle breeders in Uganda, Rwanda, Burundi, and Tanzania in different production systems.. This result is also consistent with results of a study by (Makokha *et al.,* 2007) in Western Kenya who found out that milk yield was given as the main reason for keeping cattle by farmers in areas where dairy farming is encouraged. Similarly, in the Gambia, a study by (Ejlertsen *et al.,* 2012) showed that production traits were ranked highest in a selection criterion by cattle, goat and sheep breeders. Unlike results in this study, (Tano *et al.,* 2003) in West Africa illustrated that body size was ranked lowest while disease resistance was ranked highest. The difference between the results in this study and those in (Tano *et al.,* 2003) can be explained in part by alterations in farmer trait preferences over time. Preference for live weight and bigger size of the cattle in this study could be explained partly by higher sale prices for larger cattle on markets in LMICs such as Senegal. In Ethiopia's various sheep production systems, (Duguma *et al.,* 2011) demonstrated that body size was a trait of preference among sheep breeders.

Disease resistance and feed intake were assigned lower ranks of 5 and 6 by most respondents in this study respectively. The study sites proximity to the Atlantic Ocean in the Niayes area may account for the lower rank for feed intake. This is because this location's an eco-region whose climate change resistance is higher compared to other Senegalese regions and seldom experiences decreasing precipitation, hence animal feed is available for most of the year. However, this feed availability is complicated by the high population and land pressure in this region forcing some farmers to acquire supplementary feed through purchase (Bouyer *et al.,* 2014). On the other hand, the low ranks assigned to disease resistance could be due to various tsetse elimination projects supported by the government of Senegal in Niayes region resulting in low incidences of tsetse flies related cattle diseases in the study sites (Bouyer *et al.*, 2014). Generally, in this study, almost all dairy cattle traits including coat colour-a non-economic trait was identified as one of the main drivers for differences in responses between male and female respondents' main advantage for keeping exotic breeds) were ranked first (rank 1) by at least some respondents (Table 12 and Table 15). For economic traits identified, it can be explained in part to be due to the multiplicity of cattle keepers' preferred traits thus prompting livestock keepers to choose cattle breeds that are advantageous for several traits in a single animal. Mwacharo and Drucker (2005) and; Ouma *et al.,* (2007) noted that for breeding programmes targeting smallholder farmers in LMICs, livestock keepers prefer keeping breeds or species which are better in several advantageous traits. In this study, the reasons for identification of other non-economic traits such as coat colour needs further investigation as farmers often have strong reasons underlying their preference for coat colour. For instance, results from a study by (Traoré *et al.,* 2017) noted that farmers prefer cattle with a uniform reddish coat colour. The uniformity being advantageous during branding. Additionally, tsetse flies are less attracted to the reddish coat. It is therefore, notable that in Sub-Saharan Africa, both the economic and the

non-economic values of livestock need to be considered due to the multifaceted farming objectives of most smallholder dairy farmers (Bebe *et al.*, 2003).

5.2 Economic analysis of dairy cattle keeping in Senegal

5.2.1 Dairy cattle household characteristics

The finding of this study that most households practiced crop production alongside dairy production is supported by the findings of and Wilson (2018) who note that most peri-urban dwellers in Senegal practice livestock-crop farming. This practice allows smallholder dairy farmers to diversify sources of feed for their animals as they can supplement purchased feed with agricultural by-products and leftovers from their kitchens. Further, in this study, most households (75.5%) grazed their cattle and purchased some feed to supplement the grazing. Supplementary feed was mainly crop and kitchen residues. In SSA livestock-crop farming in smallholder systems is common as livestock provide manure used as crop fertilizer, draught power, and insurance should harvests fail (Amole & Ayantunde, 2016).

The result, that most households in Senegal keep indigenous zebu followed by crossbreeds and that very few keep exotic breeds agree with Craighead *et al.* (2021) . Another study in Uganda (Mugisha *et al.*, 2014) noted that local breed-types types were the most (69%) commonly kept breeds by smallholder dairy farmers, followed by Holstein Friesian cross breeds and other breeds. Although exotic breeds of higher productivity potential have been introduced in SSA, their genetic potential is not achieved because of poor adaptability to local conditions explaining why more local breeds are kept. Consequently, crossbreeding between local cattle and exotic breeds coupled with improved management has the potential of overcoming these challenges (van't Hooft *et al.*, 2012) which could explain the better adoption of these breeds compared to exotic breeds.

On cattle reproductive strategies, results of this study show that most (70.8%) of the dairy cattle keepers used natural mating with less than half using both AI and natural mating, and less than 10% using AI exclusively. This agrees with the results of studies by Craighead *et al.* (2021) in Senegal that natural mating is the most commonly used dairy cattle reproductive strategy for smallholder dairy cattle farmers, followed by a combination of AI and natural mating. Although AI is the most appropriate method of improving the genetic makeup of dairy cattle in smallholder systems, due to the logistics challenges associated with it, natural mating using quality breeding bulls is more practical (Tshering and Tamang, 2017).

5.2.2 Profitability comparison based on breed types

In this study, the lack of statistically significant differences between the breed-types for NR_{pcpa} (Table 18) means that it was not possible to make recommendations on the most beneficial breed-type. This result was consistent with results of (Ngono-Ema *et al.,* 2018) in Senegal and (Djoko *et al.,* 2003) in Cameroon that crossbreeds between the IZ and GZ was not more beneficial than the cross breed between IZ and BT. Further, the result in this study that crossbreeds did not perform better than IZ is in line with results previously reported by (Barthe, 2014) concerning the Azawack indigenous cattle breed in Senegal. However, it can be noted that IZ x BT had the highest NR_{pcpa} among the breed-types, aligning with the study of (Marshall *et al.,* 2020) who via bio-economic modelling, that was parameterized using the same data set this study drew from, found IZ x BT to be most net-beneficial. Further, studies in Malawi on dairy cattle by (Chagunda *et al.,* 2016; Gazzarin *et al.,* 2018) showed that concentrating on crossbreeds coupled with better management can be a better strategy of improving smallholder dairy enterprises' economic performance compared to concentrating on high-yielding exotic breeds. In addition, a study by (Galukande *et al.,* 2013) agrees with these results that *Bos taurus* with local cattle crossbreeds are more beneficial in terms of income per household and production per animal. Additionally, (Roschinsky *et al.,* 2014) notes that cross breeding under

suitable conditions and appropriate implementation can give a higher income and better animal performance.

5.2.3 Profitability comparison based on household groups

In this study, the average NR_{pcpa} was positive (21.7 USD) in Table 16. This translates to about 0.06 USD per cow per day, which is very small and an indication that the smallholder dairy farming in Senegal may not be a viable venture. In addition, the huge variance (SD of 202.9 USD), and that about half of the dairy-keeping households made a loss means that there are many smallholder dairy enterprises either just breaking even, or on the verge of making great losses. Given that, smallholder dairy farming is an enterprise that should generate regular income especially to agro-pastoral system households who access cash only once annually following crop harvest, being profitable for their dairy enterprises is very cardinal.

Further, the highest-earning households typically had the greatest costs as well. Additionally, a lot of households grouped in areas of low cost and income. Sales of animals made up the largest portion of revenue for the households (off the line of best fit) in Figure 5 with the greatest NR_{pcpa}, whereas animal purchases made up the largest portion of costs for the households with the lowest NR_{pcpa}. These occurrences might be interpreted in a variety of ways, for instance, animal purchases could be made as investments to grow the dairy cattle business or as a replacement for stock that had mistakenly left the herd (such as through death). Similar to emergency sales, large animal sales may be anticipated as part of a business strategy or the result of a household's need for cash. It is noteworthy that this form of study has limitations in that it only considers events that occurred during the monitoring period, which may not necessarily be a 'typical' time period for that household. The results presented in Table 17 indicate that there is a delicate balance between families earning a return on their investments in dairy cattle operations those not. Additionally, it's possible that households that recorded

losses here will turn profitable later on as a result of successful investments (like those in investing in dairy cattle). Both group 1 and group 5 are possibilities for initiatives that aim to increase local milk or meat output or the profitability of smallholder cattle businesses. The two groups kept IZ x BT breed type, which was also the breed type that was found to be the most net advantageous in (Marshall *et al.,* 2020). The most prevalent breed type in Group 3 (Fig. 6) was the IZ, and it also had the lowest total income and the lowest cost.

This can be explained by the fact that these families utilize a low-input, low-output method that is linked to relatively large herd numbers, which are typical characteristics of Senegalese cattle keepers using traditional low-input, low-output management techniques.

This study found that HBT's total cost was statistically significantly greater than IZ x BT, which was then statistically significantly higher than IZ x GZ and IZ. This is comprehensible given the variations in a number of cost factors (Table 18), particularly feed costs and animal purchasing costs. It appears that households with enhanced dairy breeds also spend more on feed since HBT had the greatest feed expenses, followed by IZ x BT, IZ x GZ, and finally IZ and HBT. As predicted given the higher purchase price of exotic or exotic-cross animals, it is also noteworthy that animal purchase prices were highest for HBT and BT x IZ

(Marshall *et al.,* 2020).

5.2.4 Drivers of profitability in dairy cattle keeping households

Models for exogenous drivers of NR levels in this study gave relatively low R^2 values. Considering that the components were exogenous to those included in the economic analysis, this poor prediction potential was to be expected. The fact that these households were more commercially oriented can be used to explain the findings that past AI usage and milk sales at the market had a beneficial impact on NR (whether pcpa or phpa). Households in Thies had a lower NR_{pcpa} than those in Diourbel, and site was kept in the final model, for NRpcpa (but not NR_{phpa}). Further research is necessary to determine the cause of this.

A bio-economic model has been used by (Marshall *et al.,* 2020) to compare the economic performance of the various breed types. Different model assumptions were employed (for simplification) even though this model used the same data as this study for parameterization. For example, as opposed to an array of breed types, household herds were assumed to consist a single breed type and a constant size (i.e., not growing or diminishing). Aside from males that were breeding, only new born animals were permitted to join the herd, and cows stayed there until they were ready to be butchered (there was no urgent sale authorized). Notwithstanding these differences, there is good agreement between the two investigations' patterns of results.

For instance, (Marshall *et al.,* 2020) revealed that HBT had the greatest overall revenue, milk income, animal sales income, total expenses, and feed costs, followed by IZ x BT, IZ x GZ, and IZ, comparable to what was seen here. The (Marshall *et al.*, 2020) study identified IZ x BT as the breed-type with the highest net returns, which is further consistent with the data presented here (though in this study this result was not statistically significant).

The substantial diversity in NR within a breed-type was a significant finding of the breed comparison in this study. This shows that not every household is profiting equally from the investment in superior breeds. Initiatives focused on using better breeds to increase the profitability of smallholder dual or dairy cattle operations must thus be cautious to concurrently address other variables that impact productivity.

CHAPTER SIX: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

This study found that dairy cattle keepers in Senegal prefer cross breed dairy cattle over exotic and local breed types due to their ability to fulfil diverse objectives of the dairy the cattle keepers. There is multiplicity of trait preferences by dairy cattle keepers in Senegal which should be considered when setting breeding objectives. Further, this study highlights the importance of obtaining feedback from dairy cattle keepers on their preferred traits and breeds to be factored in future breeding objectives. This has the ability to enhance success and sustainability of the programmes while increasing the sense of ownership by the users and is an important consideration in breeding objectives.

In this study, there was high variance in profits across the dairy cattle keeping households and many of them (almost 50%) did not make a profit throughout the monitoring period. Although it is acknowledged that smallholders retain livestock for more than simply revenue (ILRI, 2019), profitable livestock businesses may be a major motivator for households that raise cattle to invest more in them. Given the growing need for the Senegalese dairy sector to be more efficient in the face of these difficulties, the economic analysis in this study reflects "real-life" (as opposed to a simplification, as is frequently used in models), and by grouping households, the variation in responses can be observed. Risk-averse families, for example, would not wish to put into practice an intervention whose advantages, while favourable on average, might be unfavourable for certain people.

The short comings of this approach include: The extensive data needs, difficulty to clearly focus on individual interventions (for instance, acquisition of a certain breed-type, given that farmers typically maintained herds of mixed breed-types), failure to average over a long period of time and where the monitoring for long-term is possible, it is resource intensive.

6.2 Recommendations

The recommendations of this study are:

1. Crossbreeding is a breeding strategy that needs to be considered in setting an organized breeding scheme to maximize the potential benefits, and improve dairy cattle keepers' livelihoods in Senegal since it combines the advantages of local and exotic breeds.
2. Regarding dairy cattle breed improvement in Senegal, the breeding objective defined as 'Improvement of milk and meat without loss of adaptable traits (such as disease resistance and lower feed intake)' was identified and is therefore suggested. Coat colour, a non-economic trait of preference identified in this study may also be considered. However, further work is required to design appropriate breeding programmes.
3. Measures targeted at boosting smallholder dairy cattle firms' profitability and lowering the risk of making losses are highly advised. These may include reformulation of government policies to facilitate local dairy production by re-examining the ease with which cheaper dairy products from Europe are imported and mitigating unfavourable dairy production environment.

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LIST OF APPENDICES

Appendix 1: Research article published on this work:

Malenje, E.M., Missohou, A., Tebug, S., König, E.Z., Jung'a, J.O., Bett, R.C. and Marshall, K., 2022. Economic analysis of smallholder dairy cattle enterprises in Senegal. *Tropical animal health and production*, *54*(4), pp.112. https://doi.org/10.1007/s11250-022-03201-y or as a PDF here https://link.springer.com/content/pdf/10.1007/s11250-022-03201-y.pdf.

Appendix 2: The questionnaires used collect data used in this study. See attachment below.

Appendix 1(a): Dairy cattle income/ benefit and cost questionnaire

GENERAL INFORMATION

Date of survey (DD/MM/YYYY)		
Enumerators name		
Round of longitudinal data collection		
Head of household name		
Time interview started:	HH:	MM:
Information on household		
Site name		
Name of survey respondent		
Gender of respondent (code a)		
Contact phone number of survey respondent		
Relationship of respondent to household head (code b)		
Household ID (code c)	[C_____] [_____] [_____] survey-type site household	

Gender of respondent (code a)	**Respondent relationship (code b)**	**Household ID (code c)**
1 = female 2 = male	1 = household head 2 = wife / spouse 3 = other family member 4 = other non-family member	Survey type CX = longitudinal, where X = round e.g. C2 for round 2, C3 for round 3 etc. Site code 1 = Thiès / Tivaouane 2 = Touba / Mbacke

Number of wives in household (preferably from enumerator knowledge rather than direct question)? [_____]

(Question to be deleted from later Cx surveys).

1. Milk Production

1a Milking method [____]

1=by hand; 2 = by machine; 3 = by hand AND by machine

What sort of measuring jug is used? [____]

1 = 1.2litre jug provided by the project, 2 = 5litre jug provided by the project, -77 = other, describe… [_____]

Indicate in the table below milk production per milking for the day of the survey for all cows that are usually milked during that month. In the column 'quantity', enter -88 if missing data

Indicate the volume in litres to 1 decimal place. Indicate 0 in morning if only milking in evening, indicate 0 in evening if only milking in morning.

Which milking did you observe? [____] (0 = Not observed, 1 = morning, 2 = evening). If you did not observe the morning, evening or both milking then uses the farmer recorded monitoring from the day before your visit.

Tag number	Morning Milk (date measured: ___/___/___)					Evening Milk (date measured: ___/___/___)					Is the animal healthy? (0 = no, 1 = yes
	Quantity	Reason for entering missing quantity (-88) (code a)	Calf treatment (code b)	Can milk be consumed (quality) (human & calf) (1 = yes, 0 = no)	Enumerator present & observed the measuring? (1 = yes, 0 = no)	Quantity	Reason for entering missing quantity (-88) (code a)	Calf treatment (code b)	Can milk be consumed (quality) (human & calf) (1 = yes, 0 = no)	Enumerator present & observed the measuring? (1 = yes, 0 = no)	

** The milk must be recorded rounded to one decimal place. For example, 1,0 for one litre, 2,5 litres for two litres and a half.*

Reason for missing data (code a)	**Calf (code b)**
1= cow present and milking but not recorded 2= cow present but no milking due to illness 3= cow present but no milking for another reason, give reason: [_____]	1 = calf fed before milking to allow milk flow 2 = calf fed before milking because it needed milk 3= calf fed after milking because it needed milk

4=cow not present in the herd today, but NOT because it is on transhumance 5= cow not present in the herd today because on transhumance -77 = Other, specify [_____]	4= no calf -77 = Other, specify [_____]

Total quantity of milk produced today (in litres to 1 decimal place) [ ]

1b Cow Body Condition Score (Complete for C2, C8 and C14 only)

Identification de la vache	Score for each area examined					
	Side View			Rear View		
	Backbone	Ribs / Short ribs (code a)	Hip & Pins	Hip – to- Hip	Tail head	Thighs

Backbone	Ribs / Short ribs (code a)	Hip & Pins	Hip – to- Hip	Tail head	Thighs
1 = very marked 2 = slightly marked 3 = noticeable and little covered 4 = barely detectable 5 = unrepairable	1 = very marked 2 = slightly marked 3 = noticeable and little covered 4 = barely detectable 5 = unrepairable	1 = very marked 2 = Apparent and not covered 3 = very visible and covered 4 = apparent but covered 5 = difficult to locate	1 = hips are protruding / region is concave 2 = hips are visible / near concave region 3 = hips are not visible / straight Region 4 = hips barely visible / covered area and almost concave 5 = difficult to locate / region is concave	1 = DC and Deep Ligament blade 2 = DC nascent / ligament slightly covered 3 = DC barely visible / ligament is rounded and thick 4 = covered DC / ligament barely visible 5 = DC and ligament invisible	1 = very thin 2 = thin 3 = well-trained 4 = full With whatever pockets of adipose tissue 5 = Very full and plump

2. BIRTHS AND ABORTIONS. Indicate any births and abortions that have occurred since the previous enumerator visit.

For both abortion or calving			If abortion	If calving (fill one row for each calf, whether born dead or alive)					
Tag number of the dam	Breed-type of calf's sire and dam (codes: if sire / dam is purebred fill one code, if cross-bred fill two codes)	Date of abortion or calving (DD/MM/YYYY)	Reason for abortion (code a)	Born dead or alive (code b)	Sex of calf (1=male, 2=female)	Tag number of calf or VL if local male	Calf deformities (code c)	Intended use – calves born alive only (code d)	Who owns – calves born alive only (code e)
	Sire [___] [___] Dam [___] [___]								
	Sire [___] [___] Dam [___] [___]								

Reason for abortion (code a)	**Born dead or alive (code b)**	**Calf deformities (code c)**	**Intended use (code d)**	**Who owns (code e)**
1 = sickness of the dam 2 = stress (such as feed shortage) 3 = malformation 4 = traumatic (fighting in the herd, accident) 5 = toxins (poisonous grass etc.) 6 = unknown -77 = other, specify below [_____]	1 = born dead 2 = born alive 3 = born alive but then died	1 = no deformities 2 = blind 3 = lame 4 = abnormal teat number 5 = crooked feet 6 = cleft palate -77 = other, specify below [_____]	1 = keep for breeding 2 = for sale as young calf 3 = for sale as an adult animal 4 = for fattening 5 = keep for milk production 6 = unsure -77 = other, specify below [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify below [_____]

3. ENTRIES INTO HERD OTHER THAN BY BIRTH. Indicate any entries into the dairy herd other than by birth (e.g. purchase, as a gift, transhumance etc.) that have occurred since the previous enumerator visit. Cattle for fattening and trade are not included.

Tag number of animal or group code (code a)	Animal type (code b) ***	Animal age in years completed (0= birth to 12 months; 1	Breed-type of animal (codes – end of survey –if purebred fill one code, if crossbred fill two codes)	Type of entry (code c)	If entry type =1 (purchase or barter) from whom (code d	Reason for entry (code e) answer for all	Purchase price (write 0 if free)	Transport cost associated with purchase	Who paid the purchase price / transport code (code f)	Who owns (code f)	Has the animal been quarantined (1 = yes, 0 = no)

		= 12 to 24 months etc.)				the animals		(write 0 if no transport cost)			
			[_____][_____]								

Group code (code a)	**Animal type (code b)**	**Type of entry (code c)**	**If purchase of barter, from whom (code d)**	**Reason for entry (code e)**
TL = Local bull (intact) CL = Local adult male (castrated) JL = Young Local Male VL = Local Male Calf	1 = adult male – intact 2 = adult male - castrated 3 = young male (weaned but not yet reached mating age) 4 = male calves (not yet weaned) 5 = adult female- dry 6 = adult female - lactating 7 = young female (weaned but not yet reached mating age) 8 = female calf (not yet weaned)	1 = purchase, barter, 2 = arrival in loan, contract 3 = coming back of loan, contract 4 = gift, inherited, dowry 5 = returned from transhumance 6 = on loan 7 = transferred from another herd owned by the household -77 = other, specify below [_____]	1=purchased from a large private farm 2 = purchased from government / research farm 3 =purchased from a smallholder farm 4 =purchased from a middleman / trader 5 = purchased from a village market 6 = exchange with another farmer -77 = other, specify below [_____]	1 = to replace animal that died or old stock 2 = to increase herd size 3 = for breed improvement 4 = Returned from transhumance 5 = to be closer to farm (sick, milking) -77 = other, specify below [_____] **Who paid / Who owns (code f)** 1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify below [_____]

***If animal type is cow, any entry type (complete the below):

Tag number	Date of last calving (DD/MM/YY)	Parity (number of live & still-births)	Breed of Sire	Breed of Dam
			[____] [____]	[____] [____]

4. NATURAL DEATHS AND SLAUGHTER. Provide information on animals that left the dairy herd by natural death and slaughter since the previous enumerator visit. A natural death refers to all types of deaths except slaughtering.

Tag number of animal or group code (code a)	Died or slaughtered? (code b)	Cause of…		Sale price received for dead / slaughtered animal (write 0 if no sale price received)	Transport costs associated with sale of dead / slaughtered animal (write 0 if no transport cost)	Who controls any income from sale of the animal (code e)	Estimated replacement cost of animal – to purchase a new animal of exactly the same type, sex and age
		Death (code c)	Slaughtering (code d)				

Group code (code a)	**Died or slaughtered? (code b)**	**Reason for death (code c)**	**Reason for slaughter (code d)**	**Who controls income (code e)**
TL = Local bull (intact) CL = Local adult male (castrated) JL = Young Local Male VL = Local Male Calf	1 = died 2 = slaughtered	1 = death through sickness, name illness if known below [_____] 2 = death though accident, poisoning 3 = death due to calving complications 4 = death due to natural old age 5 = death from unknown reasons -77 = other, specify [_____]	1 =slaughter due to disease 2 = slaughter due to lack of feed 3 = slaughter due to traumatism 4 = slaughter due to poor reproductive performance 5 = slaughter due to old age 6 = Too difficult to manage 7 = male calf and unwanted sex 8 = slaughter for ceremonial purposes -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]

5. EXITS FROM HERD OTHER THAN BY NATURAL DEATH AND SLAUGHTER. Provide information on animals that left the dairy herd by means other than natural death and slaughter since the previous enumerator visit.

Tag number of animal or group code (code a)	Type of exit (code b)	If sale						
		Reason for sale (code c) – if Type = 1	To whom (code d)	Tel. no. of purchaser	Sale price	Transport costs incurred by the household associated with sale of animal (write 0 if no transport cost)	Brokerage costs incurred by the household associated with sale of animal (write 0 if no transport cost)	Who controls this income (code e)

Group code (code a)	**Type of exit (code b)**	**Reason for sale (code c)**	**Sold to whom (code d)**	**Control of income (code e)**
TL = Local bull (intact) CL = Local adult male (castrated) JL = Young Local Male VL = Local Male Calf	1 = sale, barter 2 = departure in loan / contract 3 = sending back of loan / contract 4 = gift, inheritance, dowry 5 = Left on transhumance 6 = Removed / stolen 7 = Transferred to another herd -77 = other, specify below [_____]	1 =ordinary / usual sale 2 = due to disease 3 = due to lack of feed 4 = due to traumatism 5= due to poor reproductive performance 6 = due to old age 7 = too difficult to manage 8 = unwanted male calf 9 = to meet unexpected expenses -77 = other, specify below [_____]	1 = sold to a smallholder farmer 2 = sold to a large private farm 3 = sold to trader / broker 4 = sold to butcher / abattoir 5 = government farm / research station -77 = other, specify below [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify below [_____]

6. CALF WEANING AND COW DRY-OFF EVENTS. Fill the table in relation to any calf weaning or cow dry-off events that have taken place since the last enumerator visit

Calf weaning event			Cow dry-off event		
Tag number of calf or VL if young local male	Date of weaning (DD/MM/YYYY)	Weaning type (code a)	Tag number of cows	Date of dry-off (DD/MM/YYYY)	Reason for dry-off (code b)

Weaning type (code a)	**Reason for dry-off (code b)**	
1 = controlled (i.e. forced) 2 = uncontrolled (i.e. natural)	1 = calf is weaned 2 = cow is in an advanced state of pregnancy 3 = cow is sick	4 = food shortage 5 = Absence of calf (could be sick or dead) -77 = other, specify

7. PREGNANCY STATUS For all the cows that were serviced naturally or inseminated since the last visit of the investigator. Also indicate cows whose gestational status was confirmed since the last visit.

Tag number of dams	Pregnancy status (code a)	Was the insemination / mating recorded previously? (0 = no, 1 = yes))	If the pregnancy or insemination not previously recorded….	
			'Mating' method (code b)	Date of 'mating' (DD/MM/YY)

Pregnancy status (code a)	**Type of mating (code b)**
1 = not sure / waiting to see if pregnant 2 = not pregnant 3 = confirmed pregnant	1 = natural 2 = AI

8. Natural mating of cows. Complete the table below for cows that were naturally mated with a bull since the last visit of the enumerator. If the bull lives with the cows then number of days = 30

Tag number of dams	Date of 1st mating (DD/MM/YY)	Number of days with the bull (or the number of days PLANNED if she is still with the bull)	Number of matings (1 mating = 1 heat event)	Identification number if bull owned by the breeder or TL (if local bull)	Code of race if the bull does not belong to the breeder (codes – separate sheet)	Origin of the bull (code a)	If bull is borrowed…	
							Bull cost per cow mated (enter 0 if 'origin of bull' = 1 or 2)	Who pays? (code b)
					[_____][_____]			

Origin of the bull (code a)	**Who pays? (code b)**	
1 = own bull 2 = bull in the area / town used for free 3 = hired bull -77 = Other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member	4 = non-household member -77 = other, specify [_____]

9. COW SERVICING BY ARTIFICIAL INSEMINATION. Fill the table below in relation to cows that have been artificially inseminated since the previous enumerator visit.

Tag number of dams	Date of exposure (DD/MM/YYYY)	Attempt number (1 = first attempt, 2 = second attempt etc.)	Breed code of sire (code – separate sheet)	AI service provider (code a)	Was synchronisation used? (0=no, 1=yes)	Total cost of this insemination, including costs of synchronization, semen, AI service provider fees etc.	Who paid? (code b)
			[__] [__]				
			[_____]				

AI service provider (code a)	**Who paid (code b)**
1 = inseminator for the government AI Program 2 = private inseminator (not doing insemination for the government AI program) 3 = inseminator provided through an NGO -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]

10. SALE OF SIRE SERVICES. Complete the following table for any sire services sold by the farmer since the previous enumerator visit

Tag number of sire or TL if local breed	Type of service sold (code a)	Sold to whom (code b)	Sale price	Who controls this income (code c)

Type of service (code a)	**Sold to whom (code b)**	**Who controls income (code c)**
1 = bull service- single female serviced 2 = bull service – multiple females services 3 = production of semen for AI -77 = other, specify [_____]	1 = smallholder farmers 2 = large private farm 3 = research or government farm 4 = government AI program 5 = private artificial insemination company -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]

11. LABOUR IN RELATION TO DAIRY. Fill the table below for all persons/labourers (family members and hired) that have been working on dairy related activities over the previous week.

First name	Labour type (code a)	If hired labour				Average hours per day spent on dairy activities	Number of days worked over the last week (spent on dairy activities)	Give the three main time-consuming activities [code e]		
		Wage unit (code b)	Wage amount per unit	Who pays? (code c)	Other benefits for hired labour (code d, list all that apply)			Activity 1	Activity 2	Activity 3
					[____] [____] [____] [____] [____]			[____] [____]	[____] [____]	[____] [____]

Labour type (code a)	**Payment unit (code b)**	**Who pays? (code c)**	**Other benefits (code d)**	**Main activities (code e)**

1 = household adult male (>15 years) 2 = household adult female (>15 years) 3 = household boy (<15 years) 4 = household girl (<15 years) 5 = hired adult female (>15 years) 6 = hired adult male (>15 years) 7 = hired girl (<15 years) 8 = hired boy (<15 years)	1 = daily 2 = weekly 3 = fortnightly 4 = monthly 5 = annually -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]	1 = clothing 2 = housing 3 = food 4 = milk 5 = other, specify below -77 = other, specify [_____]	1 = go with animal grazing 2 = feeding, including collection and preparation 3 = production of fodder 4 = watering 5 = cleaning of animal shed/ shelter 6 = collection of farm yard manure 7 = milking 8 = milk processing 9 = selling milk or milk products 10 = selling farm yard manure 11 = selling animals 12 = disease control, caring for sick animals 13 = bring animals for breeding / AI 14 = Supervising hired labour -77 = other, specify [_____]

12. ANIMAL HEALTH RECORDS – CURATIVE TREATMENTS. Complete the following details regarding any animal health care for curative treatment(s) since the last enumerator visit. (May be derived and/or confirmed by site coordinator from farmer card)

If single animal…	If applies to a group of animals…		General information		Cost of treatment course, write 0 if no cost (if group of animals or whole herd, then cost for all animals in group)							Disease treated and outcomes	
Tag number of animal or group code (code a)	Type of animal (code b)	Number receiving treatment	Date of service (DD/MM/YY)	Service provider (code c)	(Total) Drug cost	% of drug used for this animal(s)?	Additional costs (needles etc.)	Fees paid to health-care service provider	Cost of transporting animal(s) for treatment (write 0 if no cost)	Total cost for treatment	Who paid? (code d)	Disease code (code e) – up to 3	Present status of animal(s) (code f)
												[__] [__] [__]	

Group code (code a)	**Type of animal (code b)**	**Service provider (code c)**	**Who paid cost (code d)**	**Disease (code e)**	**Animal status (code f)**

TL = Local bull (intact) CL = Local adult male (castrated) JL = Young Local Male VL = Local Male Calf	1 = calves 2 = pregnant / lactating females 3 = all animals 4 = only cross-bred / exotic calves 5 = only cross-breed pregnant / lactating females 6 = all animals that are cross-breed / exotic -77 = other, specify [_____]	1 = self 2 = other farmers / neighbours / friends 3 = private veterinarian 4 = government veterinarian 5 = community animal health worker 6 = traditional practitioner 7= NGO staff -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]	1 = pasteurellosis 2 = trypanosomosis 3= FMD 4 = CBPP 5 = lumpy skin disease (LSD) 6 = blackquarter 7 = heartwater 8 = worm infestation 9 = piroplasmoses 10 = mastitis 11 = injuries (fractures) 12 = botulism 13 = enterotoxaemia 14 = Thileria Parva 15 = Anthrax -77 = other, specify [_____]	1 = still sick 2 = recovered 3 = died 4 = slaughtered 5 = sold -77 = other, specify [_____]

13. ANIMAL HEALTH RECORDS – PREVENTATIVE AND OTHER TREATMENTS. Complete the following details regarding any animal health care for preventative treatment(s), or improved management practices, since the last enumerator visit. (May be derived and/or confirmed by site coordinator from farmer card)

If single animal…	If applies to a group of animals…		General information		Cost of treatment course, write 0 if no cost (if group of animals, then cost for all animals in group)							Activity type (code e)
Tag number of animal or group code (code a)	Type of animal (code b)	Number receiving treatment	Date of service (DD/MM/YY)	Service provider (code c)	Total drugs cost	% of drug used for this animal(s)?	Additional costs (needles, sprayers etc.)	Fees paid to health-care service provider	Cost of transporting animal(s) for treatment (write 0 if no cost)	Total cost	Who paid? (code d)	

Group code (code a)	**Type of animal (code b)**	**Service provider (code c)**	**Who paid cost (code d)**	**Activity (code e)**
TL = Local bull (intact) CL = Local adult male (castrated) JL = Young Local Male	1 = calves 2 = pregnant / lactating females 3 = all animals 4 = only cross-bred / exotic calves 5 = only cross-breed pregnant / lactating females 6 = all animals that are cross-breed / exotic	1 = self 2 = other farmers / neighbours / friends 3 = private veterinarian 4 = government veterinarian 5 = community animal health worker	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]	1= vaccination for pasteurellosis 2 = vaccination for FMD 3 = vaccination for LSD 4 = vaccination for Blackquarter 5= vaccination for botulism 6= vaccination for enterotoxaemia

VL = Local Male Calf	-77 = other, specify below [_____]	6 = traditional practitioner 7= NGO staff -77 = other, specify [_____]		7 = dipping 8 = de-worming 9 = « flushing » (feeding up pre-mating) 10= « steaming » (keeping healthy while pregnant) - (incl. Vitamins) -77 = other, specify [_____]

14. GRAZING RECORDS. Complete the table if one or more of the cows has been put out to pasture since the last visit of the enumerator. Use one row for each grazing location.

Number of days since the last visit of the investigator [ ]
Number of days the animals were NOT pastured: [ ]
Number of days the animals HAVE been pastured [ ].
The detail of these days is to be indicated in the table below:

No. days since last visit this pasture has been used	Type of grazing land (code a, list all that apply)	If crop, type (code b)	Distance between the pasture and the housing of animals (km)	Quality of the feed (code c)	No. hours they stay each day	Type of local breed animals in the group code (indicate all that apply)	No. of local animals (put in same order as type)	Type of cross or exotic breed animals in the group code (indicate all that apply)	No. of cross or exotic animals (put in same order as type)	Is there any payment for the use of the pasture (whether monetary or in kind, eg manure) (0 = no, 1 = yes). If yes, complete the next table
	[__] [__] [__] [__]					[__] [__] [__]	[__] [__] [__]	[__] [__] [__]	[__] [__] [__]	

Type of grazing land (code a)	**Type of crop (code b)**	**Quality of feed (code c)**	**Type of animal (code d)**

1 = community land (open grass land) 2 = state land (forest land, schools) 3 = own grazing land with natural pasture 4 = own grazing land with improved pasture 5 = own cropped land 6 = paid for or rented cropped land 7 = roadside grazing -77 = other, specify [_____]	1 = Maize / corn (stover) 2 = Millet 3 = sorghum (stalks) 4 = rice (straw) 5 = wheat (straw) 6 = bean 7 = ground-nut (haulms) 8 = cowpea -77 = other, specify [_____]	1 = very poor for this season 2 = somewhat poor for this season 3 = average for this season 4 = somewhat good for this season 5 = very good for this season	1 = all in herd 2 = calves 3 = immature males / heifers 4 = cows - non-lactating and not pregnant 5 = cows – lactating or pregnant 6= bull -77 = other, specify [_____]

15. Complete the table below for payments relating to pasture and made since the last visit of the investigator, whether monetary payments (cash) or other (eg exchange against manure).

Type of grazing land (code a, list all that apply)	**If crop, type (code b)**	**Type of payment (code c)**	**If monetary payment, how much?**	**Who pays? (code d)**	**Date of payment**	**Period covered by the payment (mths, indicate 0.25 for 1 week)**

Type of grazing land (code a)	**Type of crop (code b)**	**Type of payment (code c)**	**Who pays? (code d)**
1 = community land (open grass land) 2 = state land (forest land, schools) 3 = own grazing land with natural pasture 4 = own grazing land with improved pasture 5 = own cropped land 6 = paid for or rented cropped land 7 = roadside grazing -77 = other, specify [_____]	1 = Maize / corn (stover) 2 = Millet 3 = sorghum (stalks) 4 = rice (straw) 5 = wheat (straw) 6 = bean 7 = ground-nut (haulms) 8 = cowpea -77 = other, specify [_____]	1 = currency / cash 2 = in-kind -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]

16. FEEDING OTHER THAN GRAZING. Please fill the below in relation to feeding practices (other than grazing) on the day before the enumerator visit. Use one row per 'type of food' and 'type of animal fed' combination. Enumerators please verify feeding practices / amounts.

Feed type (code a)	Practice typical since last visit? (0=No, 1=Yes)	If crop, type (code b)	Type of animal fed			If animals in the group are fed individually		If animals in the group are fed collectively		Was the feed purchased (0=no, 1=yes)
			Type of animal (code c, list all that apply)	Type of breed (code d, list all that apply)	Number	Units (code e)	Units fed PER animal	Units (code e)	Units fed TO GROUP of animals	
			[__] [__] [__]	[__] [__] [__]						

Feed type (code a)	**Type of crop (code b)**	**Type of breed (code d)**	**Feed unit (code e)**
1 = natural pasture, cut and served with fresh 2 = natural pasture, cut and stored dry (hay) 3 = natural pastures, cut and ensiled 4 = crop stalks, sliced and served with fresh 5 = crop stalks, cut and stored dry (hay) 6 = crop stalks, chopped and ensiled 7 = crop - cut and served with fresh, complete 8 = crop - cut and stored dry, complete 9 = groundnut cake 10 = food concentrates, made on the farm 11 = Food purchased concentrates 12 = rice bran 13 = millet bran 14 = cornmeal 15 = peanut shells 16 = ball mil 17 = Salt Lick 18 = Cardboard / Paper 19 = cottonseed -77 = Other, specify [_____]	1 = Maize / corn (stover) 2 = Millet 3 = sorghum (stalks) 4 = rice (straw) 5 = wheat (straw) 6 = bean 7 = ground-nut (haulms) 8 = cowpea -77 = other, specify [_____] **Type of animal (code c)** 1 = all the herd 2 = calves 3 = young male / heifers 4 = cows - not lactating and not pregnant 5 = cows lactating and / or pregnant 6 = bull -77 = Other, specify below [_____]	1 = local / indigenous 2 = cross between indigenous and exotic 3 = exotic	**1 =** kg **2 =** wheel barrow **3 =** donkey cart load **4** = bunch / bundle **5 =** heap **6 =** hand cart load **7 =** pick-up truck load **8 =** tin 9 = 20 litre bucket 10 = handful -77 = Other, specify below [_____]

17. FEED PURCHASES. Complete the following in relation to any feed purchased since the last enumerator visit

(Check and add feeds from Table 16 and ask farmer for any others)

Type of feed (code a)	If crop / stover, type of crop (code b)	Units (code e)	Total Cost	Units purchased	Cost per unit	Transport cost for all units purchased	Who paid the feed and transport costs (code c)	Source (code g)

Type of feed (code c)	Type of crop (code d)	Feed unit (code e)	Who paid (code d)	Source (code e)
Use codes from table above	Use codes from table above	Use codes from table above	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]	**1** = own farm **2** = other farms, free 3 = other farms, paid 4= communal – free access (e.g. roadside) 5 = communal – paid 6 = purchased from feed supplied -77 = other, specify [_____]

18. WATERING PRACTICES. Indicate below how water has been provided for the dairy cattle since the last enumerator visit. One line for each source of water. *To one decimal place

Source of water (code a)	Animal type watered			Distance to water (km)*	Frequency of watering per day (code d)	If individual watering, quantity provided to each animal each day, if known (litres)	If group watering quantity provided to group each day, if known (litres)
	Animal type (code b, list all that apply)	Breed-type (code c, list all that apply)	Number				
	[__] [__] [__] [__] [__]	[__] [__] [__]					

Source of water (code a)	Animal type (code b)	Breed type (code c)	Frequency of watering (code d)
1 = well off the farm 2 = well on the farm 3 = river / stream off the farm 4 = river / stream on the farm 5 = pond / creek on the farm 6 = pond / creek off the farm 7 = tap water in the farm 8 = tap off-farm	1 = all the herd 2 = calves 3 = young male / heifers 4 = cows - not lactating and not pregnant 5 = cows lactating and / or pregnant 6 = bull	1 = local / indigenous 2 = cross between indigenous and exotic 3 = exotic	1 = one time per day 2 = two times per day 3 = three times per day 4 = throughout the day (cattle drink at any time) -77 = Other, specify [_____]

9 = borehole 10 = collected rainwater -77 = Other, specify [_____]	-77 = Other, specify [_____]		

19. WATER PURCHASES. Complete the following in relation to any water purchases since the previous enumerator visit, including any water access or permit fees. Do not include any water permit fees (which are captured in question 28)

Source of water (code a)	Units of water (1 = litre, 2 = m^3)	Number of units of water	Cost of water	Transport cost	Who paid (code b)	% of Cost for water used in dairy enterprise	Who purchased from (code c)

Source of water (code a)	Who paid (code b)	Who purchased from (code c)
1 = well off the farm 2 = well on the farm 3 = river / stream off the farm 4 = river / stream on the farm 5 = pond / creek on the farm 6 = pond / creek off the farm 7 = tap water in the farm 8 = tap off-farm 9 = borehole 10 = collected rainwater -77 = Other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]	1 = SDE (Senegalese Waters) 2 = water seller 3 = service of the hydraulic 4 = other farmer 5 = private enterprise -77 = other, specify [_____]

20. FRESH MILK Fill the following in relation to milk produced on the farm on the last milk recording day before the enumerator visit

Total milk produced on the last milk recording day, from milk recording book (litres, to one decimal place) [_____]

Check that the amount does not differ much from the amount given in Table 1 (amount of milk the day of the visit). If there is a significant difference, indicate the reason here: _____ (fed to calves removed – does NOT happen)

How this milk is utilised: give amount in litres and check the sum of these columns adds to the total above (litres to one decimal place)	For fresh milk sold (total must be equal to 'total amount sold fresh' – column 6)

Amount consumed by the household	Amount given away	Amount wasted	Quantity processed	Total Amount sold fresh	Unit of sale (code a)	Number of units sold	Sale price for single unit sold	Transportation cost for ALL units sold	Buyer type (code b)	Who controls this income (code c)
(leave blank)										

Unit of sale (code a)	**Buyer type (code b)**	**Control of income (code c)**
1 = 250 ml 2 = 500 ml 3 = 1 litre 4 = 250 grams 5 = 500 grams 6 = 1 kilogram -77 = other, specify [_____]	1 = at home or farm to individual customers 2 = at home or on the farm traders 3 = market 4 = to a dairy cooperative 5 = to a dairy processing unit 6 = directly to a school / hospital / restaurant -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]

21. PROCESSED MILK. Fill the following in relation processed milk products, made from the milk produced on the last recording day before the enumerator visit.

Product (code a)	Production unit (code b)	Total number of units produced (using milk from the day before yesterday)	How units are utilised				For units sold				
			Number of units consumed by the household	Number of units given away	Number of units wasted	Number of units sold	Sale price PER UNIT	Sale price for ALL units sold	Transportation cost for ALL units sold	Buyer type (code c)	Who controls this income (code d)

Processed milk product (code a)	**Production unit (code b)**	**Buyer type (code c)**	**Control of income (code d)**
1 = Curd 2 = Diw Nior ('ghee') -77 = Other, specify [_____]	1 = 250 ml 2 = 500 ml 3 = 1 litre 4 = 250 grams 5 = 500 grams 6 = 1 kilogram -77 = Other, specify [_____]	1 = at home or farm to individual customers 2 = at home or on the farm traders 3 = market 4 = to a dairy cooperative 5 = to a dairy processing unit 6 = directly to a school / hospital / restaurant -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]

22. HOUSEHOLD MILK / MILK PRODUCT CONSUMPTION.

Consumption of milk and milk products by household members. Complete the table below for the consumption of milk and dairy products, for the week before the visit of the investigator. This question should be asked the wife (or wives) of the household head. Complete a row for each product (including fresh milk). Note that this table applies to both dairy products produced by the household and those purchased.

Was this question answered by a household adult female (0=no, 1 = yes) [___].

Milk product consumed by household (code a)	Number of days last week during which the product has been consumed?	Unit (code b)	Quantity consumed – total for the week	Was this product produced by the household (code c)	Has this type of person in the household consumed this product? (1 = yes, 0 = no, -99 does not apply if the class is not in the household)					
					Household adult males	Household adult females	Household male children, 5 to 15 years of age	Household female children, 5 to 15 years of age	Household male children, < 5 years of age	Household female children, < 5 years of age

Products (code a)	**Unit of consumption (code b)**	**Product consumed by the household? (code c)**
1 = fresh milk 2 = curd 3 = Diw Nior ('ghee') 4 = butter 5 = quark 6 = cheese 7 = Ice creams 8 = yogurts -77 = Other, specify [_____]	1 = litre 2 = kg -77 = Other, specify below [_____]	1 = yes 2 = No, the household has purchased 3 = no, the household was exchanged against another product / good 4 = no, the household was given it

23. MANURE COLLECTION & STORAGE.

Complete the table below in relation the main location for animals since the last enumerator visit. The Main Animal Location is where most of the animals are kept, most of the time.

Day-time				**Night-time**			
Main animal location (Code a)	Manure is collected (i.e. dry-lot)? (0 = No, 1 = Yes)	If manure collected, storage method (code b & percent stored by this method)	If manure collected, length of storage (days)	Main animal location (Code a)	Manure is collected (i.e. dry-lot)? (0 = No, 1 = Yes)	If manure collected, storage method (code b, percent stored by this method)	If manure collected, length of storage (days)

		[……..][……..] [……..][……..] [……..][……..]	[……..] [……..] [……..]			[……..][……..] [……..][……..] [……..][……..]	[……..] [……..] [……..]

Main animal location (code a)	**Manure storage / collection method (code b)**
1 = On pasture 2 = On cropping land 3 = On ground (non-pasture / non-cropping) 4 = Inside - Housed / confined (walls and/or roof etc.) -77 = Other, specify: [_____]	1 = solid storage in stacks / piles (stored in a big heap) 2 =deep bedding (manure mixed with bedding e.g. straw) 3 = slurry liquid in an uncovered tank / pond (mixed with water and stored as slurry in an open-to tank / pond) 4 = slurry liquid in a covered tank / pond (mixed with water and stored as slurry in an open-to tank / pond). Please name material cover is made from (e.g. plastic, straw, wood) [_____] 5 = anaerobic lagoon (slurry washed out and stored in lagoon) -77 = other, please describe [_____]

24. MANURE. Complete the table below for manure production since the last visit of the investigator. This table applies only to the collected manure (not considering manure deposited on pasture or cropping land).

Indicate how much falls into the following categories (% total to 100)						For the manure sold (one row per buyer)							Manure to get rid of / destroy?			
Sold (%)	Given away (%)	Destroyed (%)	Used on farm (%)	Still stored on the farm (%)	Other, specify [_____]	Sales unit (code a)	No. Units sold	Sale price PER UNIT	Cost packaging per unit	Cost of transport for ALL units sold	Buyer (code b)	Who controls the money received (code c)	Unit (code a)	No. of destroyed units	Price PER UNIT	Who pays? (code c)
(leave blank)																

Unit of sale / for destruction (code a)	**Buyer (code b)**	**Who controls the revenue / pays ? (code c)**
1 = bag : Indicate kg per bag [_____] 2 = wagon - indicate kilograms per wagon [_____]	1 = another farmer or rancher 2 = large private farm 3 = trader	1 = male household member 2 = female household member 3 = jointly between female and male household member

-77 = Other, specify [_____] and give the equivalent in kg per unit [_____]	-77 = Other, specify [_____]	4 = non-household member -77 = other, specify [_____]

25. LOANS. Give details of any loans taken out in relation to the dairy enterprise since the previous enumerator visit.

Reason for loan (code a)	Who took out the loan (code b)	Who pays the repayment (code c)	Total amount of loan	Date loan was taken out (MM/YYYY)	Any grace period before repayment start (months)	Duration of repayment (months)	Interest rate for first year of loan (%) – 0 if no-interest loan	Loan provider (code c)	Was this loan specifically taken out in relation to the keeping of cross-bred / exotic animals (0=no, 1=yes)

Reason for loan (code a)	**Who took out loan (pays the repayments (code b)**	**Loan provider (code c)**
1 = purchase dairy animals 2 = construct or improve animals house / shed 3 = purchase land 4 = purchase chilling equipment 5 = purchase automated milker 6 = cover running costs 7 = pay salaries 8 = buy other materials / equipment -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member	1 = government bank/agency 2 = commercial bank 3 = informal lenders 4 = co-operative 5 = project / NGO 6 = self Help group or savings club 7= relatives or friends 8 = Fonstab 9 = micro-credit -77 = other, specify [_____]

26. DRAUGHT-POWER AND TRANSPORT. Complete the following table if any animals of the dairy herd were used for draught-power or transport since the previous enumerator visit. Use one row per animal.

Animal id or group code (code a)	Type of activity (code b)	Number of days involved in activity	Average number of hours per day involved in activity	If any income from this activity, specify daily income	Who controls this income (code c)

Group code (code a)	**Type of activity (code b)**	**Who controls income (code c)**
TL = Local bull (intact)	1 = draught-power	1 = male household member

CL = Local adult male (castrated) JL = Young Local Male VL = Local Male Calf	2 = transport	2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]

27. ANY OTHER EXPENSES. Give details of any other expenses relating to the dairy enterprise (not captured above) since the previous enumerator visit.

Types of expenses	Date paid (DD/MM/YY)	Time period that fee relates to (code a)	Amount paid	Who paid this cost (code b)	Renewal of previous fee (0=no, 1=yes)
Tethering fees					
Rental fees – animal housing					
Watering permit or water access fees					
Grazing fee					
Fodder collection fee: name fodder type [_____]					
Rental fees – land					
Rental fees – equipment					
Miscellaneous small equipment e.g. buckets, ropes: name equipment Below [_____]					
Group or co-operative fees: name group {_____]					
Other, specify [_____]					

Period (code a)	**Who pays? (code b)**
1 = weekly 2 = monthly 3 = annually 4 = one-off payment -77 = other, specify [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]

28. ANY OTHER INCOME. Give details of any other income relating to the dairy enterprise or dairy related activities (not captured above) since the previous enumerator visit.

Income type	Date received (DD/MM/YYYY)	Total amount received	Who controls this income (code a)	Comments if any
Milking of cows belonging to other				
Caring of cows belonging to others				
Hire-out of dairy equipment				
Other, specify below [_____]				
Other, specify below [_____]				
Other, specify below [_____]				
Who controls this income (code a)				
1 = male household member 2 = female household member 3 = jointly between female and male household member 4 = non-household member -77 = other, specify [_____]				

29. USE OF DAIRY RELATED INCOME. Indicate what the household income from the dairy enterprise has been spent on since the previous enumerator visit. Ask this question specifically to the household member who controls the income (such as the head household female for female controlled income).

	Does this situation apply (0=no, 1=yes)	What was the income spent on? (code a, list all that apply)	Was this question answered by the person/people who controls the income (0=no, 1=yes)
Dairy income controlled by female household member		[___] [___] [___] [___] [___] Other [_____]	
Dairy income controlled by male household member		[___] [___] [___] [___] [___] Other [_____]	
Dairy income jointly controlled by female and male household member		[___] [___] [___] [___] [___] Other [_____]	
Use of dairy income (code a)			
1 = food (for the household) 2 = education fees		6 = activities for dairy farming 7 = other agricultural activities	

3 = medical expenses (for the household) 4 = spending on home improvement (e.g renovation of the roof) 5 = other expenses for the household	8 = non-agricultural activities (e.g trade, business) 9 = savings 10 = feed for animals 11 = medical expenses for the animals -77 = Other, specify in the appropriate box

At the end of the survey:

Thank the respondent. Ask the farmer if they have any questions for you. Explain that you will return in a few weeks.

Time of finishing the survey:	HH:	MM:

Quality Assurance aspects

Enumerator: Enter your comments here after completing the survey

Date_____ Nom_____ Signature_____

Supervisor: Enter your comments here after reviewing the questionnaire

Date_____ Nom_____ Signature_____

Database Manager: Enter your comments here after entering the data / checking

Date_____ Nom_____ Signature_____

Milk sheet collected from farmer (0=no, 1= yes) [_____]

Appendix 1(b) . Adult female cattle breed and trait preferences questionnaire

1. GENERAL INFORMATION

Date of survey (DD/MM/YYYY)				
Enumerators name				
Head of household name				
Did the household (**head and spouse**) consent to the interview or project? (0=no, 1=yes)				
If no, why (code a)				
If no, request a replacement household from supervisor (and continue with this questionnaire)				
Time interview started:	HH:	MM:	Common currency unit	
Information on site and household				
Site name				
Village name				
Head of household name *(Replacement name if original household refuses)*				
Name of survey respondent				
Relationship of respondent to household head (code b)				
Household GPS coordinates	Latitude (N/S)			
	Longitude(E/W)			
Household ID (code c)	[__HH__] [_____] [_____] survey-type site household			

No consent reason (code a)	**Respondent relationship (code b)**	**Household ID (code c)**
1 = Respondent refuses to participate 2 = Respondent does not have the time 3 = Household head (or another knowledgeable household member) is not present at the house -77 = Other, specify below [_____]	1 = household head 2 = wife / spouse 3 = other family member 4 = herd's man (paid labour) -77 = other non-family member [_____]	<u>Survey type</u> HH = household head baseline <u>Site code</u> 1 = Thies /Tivaouane 2 = Touba /Mbacke

Please use the following codes:

- Does not apply (question was not answered) = -99
- Missing data / did not respond = -88
- Other = -77 (write the response "other" in the space provided in each table; if there is more than one, separate with a comma)

What is the "type" of household?

Q1. Is the household head or member of household available? (0= No, 1= yes)	
Q2. Does the household have a herd's man or herder (0= No, 1= yes)	

- Q1 = Yes and Q2= No ⟹ Type 1, all questions must be asked to the household head or representative
- Q1=Yes and Q2=Yes ⟹ Type 2, all questions must be asked to the household head or representative but some questions could be asking to the herder
- Q1= No and Q2=No ⟹ Type 3, questions on section 1 and 2 should be asked to the herder. If possible, questions on section 3 should be asked to the household head (owner of the herd)

2. INFORMATION ON THE DAIRY PRODUCTION SYSTEM

2.1 Number of years in cattle and dairy rearing

2.1.1 Number of years in cattle rearing: (number of years) [_____]

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

2.1.2 Number of years in dairy cattle rearing, where dairy cattle are considered animals of any breed (including local, cross-breed and exotic) that produce milk for human consumption and / or sale: (number of years) [_____]

2.2 Type of dairy production systems

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

2.2.1 Number of dairy herds, where a dairy herd is considered a group of dairy animals kept in a separate location for most of the year: (number of herds) [_____]

2.2.2 Fill in the table below in relation to each dairy herd

Herd number	Cattle breed-type (code a, list all that apply)	Feeding system (code b) list all that apply		Location of herd (code c)		Does this herd belong to you (0=No, 1=Yes)	Do you manage this herd? (0=No, 1=Yes)	Did this herd exist 5 years ago? (0=no, 1=yes)
		Rainy season	Dry season	Rainy Season	Dry season			
1	[___] [___] [___]	[___] [___] [___]	[___] [___] [___]					

Cattle breed type (code a)	Feeding systems (code b)	Location of herd (code c)
1 = local / indigenous 2 = cross-breed (between local / indigenous and exotic) 3 = exotic	1 = mainly free grazing 2 = mainly stall feeding or feeding whilst tethered 3 = mix of the above -77= other, specify below [_____]	1 = close to household - within 15 minutes' walk 2 = away from household but within the same arrondissement as the household 3 = in another arrondissement to the household

2.3 Number of dairy animals

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

2.3.1 Fill in the table below in relation to the number of dairy animals owned by the household FOR THE FIRST HERD

Breed-type	Animal-type	Number of animals owned				Number of animals	
		By male	By female	Jointly	Total	Managed but does not belong to household	Belong to household but not managed
Local	Bull						
	Adults Male castrate						
	Cow						
	Immature females/ heifers						
	Calves						
Cross breeds	Bull						
	Adults Male castrate						
	Cow						
	Immature females/ heifers						
	Calves						
	Bull						

Exotic breeds	Adults Male castrate						
	Cow						
	Immature females/ heifers						
	Calves						

2.3.2 Fill in the table below in relation to the number of dairy animals owned by the household for the second herd

Breed-type	Animal-type	Number of animals owned				Number of animals	
		By male	By female	Jointly	Total	Managed but does not belong to household	Belong to household but not managed
Local	Bull						
	Adults Male castrate						
	Cow						
	Immature females/ heifers						
	Calves						
Cross breeds	Bull						
	Adults Male castrate						
	Cow						
	Immature females/ heifers						
	Calves						
Exotic breeds	Bull						
	Adults Male castrate						
	Cow						

	Immature females/ heifers						
	Calves						

2.4 Reasons for keeping dairy animals

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Indicate the three main reasons for keeping dairy animals

Primary reason (code a)	Secondary reason (code a)	Tertiary reason (code a)

Reason for keeping dairy animals (code a)	
1 = savings / insurance	6 = domestic milk consumption
2 = income from sale of milk or milk products	7 = manure for cropping
3 = income from sale of calves	8 = ceremonial or dowry purposes
4 = income from sale of manure	9 = prestige
5 = income from sale of breeding animals or their services	10 = principal activity
	-77 = other, specify below
	[_____]

2.5 Milk products sold and marketing information

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Indicate the three main types of milk products sold over the last 12 months, and main marketing method (if only one or two types of product are sold, leave the other rows blank)

Rank of product sold	Type of product (code a)	Main marketing method (code b)	Principal advantage associated with the buyer (code c)	Main problem associated with buyer (code c)	From which herd? (code d)
Primary					
Secondary					
Tertiary					

Type of product sold (code a)	Marketing method (code b)	Advantage or problem associated with buyer (code c)	which herd (code d)
1 = fresh milk	1 = sold from house to individual customers	0= only one buyer is available	1= 1st herd

2 = soured milk 3 = Ghee 4 = cheese -77 = other, specify below [_____]	2 = sold from house to milk traders 3 = sold from market 4 = sold through a dairy co-operative 5 = sold directly to a chilling plant / dairy processing company 6 = sold directly to a school / hospital / restaurant -77 = other, specify below [_____]	1 = No advantage/ no problem 2 = does /does not always give good price 3 = always buys /unable to sell all of my product produced 4 = purchases throughout the year/only purchases at specific times of the year 5 = Pay in time /does not pay in a timely manner 6 = easy to transport product to this buyer/ difficult to transport product to buyer 7 = gives inputs or services /does not give inputs or services on credit in exchange for product -77 = other, specify below [_____]	2= 2nd herd 3= the 2 herds -77 = other, specify below [_____]

2.6 Use of, and preference for, dairy breed-types

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

2.6.1 Does the household own, keeps, owned or had raised cattle of other breeds other than locale breed (0=no, 1=yes) [____]

If no, go to 2.6.2.

If yes, complete the table below

Year in which household first used a non-local breed-type (year)	Whose decision was it to use the non-local breed-type (code a)	Who recommended use of the non-local breed-types (code b)	How was the first non-local breed type acquired (code c)	Is the household still using a non-local breed-type (0=no, 1=yes)	If the household has stopped using non-local breed types, give main reason (code d)

Decision maker (code a)	Who recommended use (code b)	Means of acquisition (code c)	Reason for stopping use (code d)

1 = household male 2 = household female 3 = jointly between household male and female 4 = non-household member	1 = no recommendation (own initiative) 2 = extension officer 3 = veterinarian / animal health worker 4 = family member 5 = neighbour / friend 6 = dairy co-operative 7 = NGO -77 = other, specify below [_____]	= upgrade from local breed through government AI program 2= upgrade from local breed through private AI service 3 = upgrade from local breed through the use of a bull 4 = purchase of cross-bred or exotic animal = gift of cross-breed or exotic animal -77 = other, specify below [_____]	1 = unable to access 2 = too expensive to access or lack of credit to access 3 = too difficult to manage 4 = unable to provide sufficient feed 5 = believe the local breed-type is more profitable / beneficial to keep -77 = other, specify below [_____]

2.6.2. If the household has NOT ever used non-local dairy breed-types (i.e. cross-breed or exotic), complete the following table

Main Reason for not using non-local breed-type (code a)	Do you plan to use non-local breed-types in the future? (code b)
Reason for not using (code a)	Planned use (code b)
1 = unable to access 2 = too expensive to access or lack of credit to access 3 = too difficult to manage 4 = unable to provide sufficient feed 5 = believe the local breed-type is more profitable / beneficial to keep 6 = was not aware this was an option -77 = other, specify below [_____]	0 = no 1 = yes, within next 1 to 3 years 2 = yes, but in more than 3 years' time 3 = unsure

2.6.3 Rank the follow traits by level of importance to your dairy farm

Trait	Is this trait important (0=no, 1= yes)	If yes, please rank*
milk yield		
Milk quality (% fats)		
sale value of calves		
adaptability to local conditions		
Disease resistance		
easy to manage or handle		
feed intake		
reproductive qualities		
calf mortality		
Coat colour		
udder conformation or size		
live weight or size of animal		
Level of importance (code)		
*Ranking by order of importance: 1= most important; 2=second most important etc.		

2.6.4. If the respondent has knowledge of more than one breed-type, fill the table in relation to the most and least preferred breed-type

What are the cattle breed types that the respondent owns, manage or knows (use the table of cattle breed codes)?

Local breed: [____] [____]; [____] [____]; [____] [____]

Cross breeds: [____] [____]; [____] [____]; [____] [____]

Exotic breeds: [____] [____]; [____] [____]; [____] [____]

Breed type	Preference (Code a)	Specific breed code, if known (codes – end of survey)	Main reasons for preference (code b or code c)
Local breed			
Cross breed			
Pure breed			

Preference (code a)	Main reason for preference	Reason for inconvenience (code c)
1 = high preference 2= Moderate preference 3= Low preference 4 = indifferent	0= no particular reason 1 = high milk yield 2 = good milk quality 3 = high sale value of calves 4 = well adapted to local conditions 5 = good disease resistance 6 = easy to manage 7 = low feed intake 8 = good reproductive rates 9 = low calf mortality 10 = nice coat colour 11 = adequate conformation of the udder 12 = weight and conformity of the animal 13 = fast growth 14 = adapted to long to walk -77 = other, specify below [_____]	0= no inconvenience 1 = low milk yield 2 = poor milk quality 3 = low sale value of calves 4 = poorly adapted to local conditions 5 = poor disease resistance 6 = hard to manage 7 = high feed intake 8 = poor reproductive rates 9 = high calf mortality 10 = bad skin colour 11= inadequate shape and size of the udder 12= inadequate weight and conformity of the cow 13 = poor growth rate 14 = not adapted to long walk -77 = other, specify below [_____]

2.7 Source and criteria for selection of male and female dairy animals for mating

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Indicate in the table below the sources of males and females used for breeding. Please fill the whole table and not only cattle that are owned by the household

	Used for breeding (0=not used, 1=yes, -99=not applicable)			Most preferred source (tick the ONE most preferred source for each sex)
	Breeding animal = local / indigenous breed	Breeding animal = cross-breed (between	Breeding animal = exotic breed	

		local and exotic)		
MALES				
Use best male from own herd				
Use of a bull in a transhumant herd				
Gift of breeding male				
Borrow breeding male (used for free)				
Hire of breeding male (used with some form of payment)				
Purchase of breeding male from large scale / commercial dairy farm				
Purchase of breeding male from a market in the neighbourhood				
Purchase of breeding male from a market outside the locality				
Purchase of breeding male from another smallholder / friend / neighbour				
AI - government program				
AI – private (other than the government program)				
AI – other, specify below [_____]				
Other, specify below [_____]				
FEMALES				
Use females from own herd				
Priority is given to the best female in my herd				
Purchase of breeding female from a large scale / commercial dairy farm				
Purchase of breeding female from a livestock market in the neighbourhood				
Purchase of breeding female from a livestock market outside the locality				
Purchase of breeding female from another smallholder / friend / neighbour				
Other, specify below [_____]				

2.8 Access to artificial insemination (AI) services

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

2.8.1 Fill the table in relation to use of AI over the last 2 years

Have you used AI in the last 5 years (0=no, 1=yes)	
If AI has been used in the last 5 years	
Who was the main AI service provider (code a)	
What was the 2 major problems (if any) with the AI service from your main provider (code b)	[____] [____]
Did you have a choice of which breed of male your female(s) would be inseminated with (code c)	
If AI has NOT been used within the last 5 years	
Why have you not used AI (code d)	

Main AI service provider (code a)	Problem with main AI service provider (code b)	Choice of breed of AI male (code c)	Reason for not using AI (code d)
1 = inseminator for the government AI program 2 = private inseminator (not doing AI for the government program) 3 = inseminator provided through an NGO 4 = other, specify below [_____]	1 = no problems with the AI service 2 = too expensive 3 = long distance to inseminator 4 = too many repeats attempt to conceive) 5 = no variety of breeds on offer 6 = not enough information on the AI sire 7 = Unskilled and not qualified inseminators -77 = other, specify below [_____]	0 = no 1 = yes - limited 2 = yes - extensive 3= not sure	1 = was not aware it was available 2 = prefer to use live sires 3 = AI service too expensive 4 = AI service of poor quality -77 = other, specify below [_____]

2.9 Animal health

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

2.9.1. Fill the below table in relation to the three most significant disease or symptoms in terms of mortality (death) or morbidity (illness) that have affected your animals in the past 5 years

Rank of disease / symptoms	Diseases (code a)		For which herd (code C)		Symptoms (code b)		For which herd (code C)
	Local / indigenous animals	Cross-bred or exotic animals			Local / indigenous animals	Cross-bred or exotic animals	
Primary							
Secondary							
Tertiary							

Diseases (code a)	Symptoms (code b)		For which herd (code C)
0= no disease 1 = pasteurellosis 2 = trypanosomosis 3 = foot and mouth disease 4 = contagious bovine pleuropneumonia 5 = lumpy skin disease 6 = blackquarter 7 = heartwater 8 = worm infestation 9 = piroplasmoses 10 = mastitis 12 = botulism 13 = enterotoxaemia 12 = -77 = other, specify below [_____]	0= no symptoms 1 = skin problems – lumps, rash, scabs, hair loss 2 = eye problems – red eye, tearing, blindness, worms 3 = foot problems – lameness, sores, foot rot 4 = nervous signs – circling, aggressiveness, madness 5 = wounds 6 = diarrhoea in calves 7 = diarrhoea in adults 8 = bloating	9 = bottle jaw 10 = red urine 11 = weakness 12 = fever 13 = abortion/ miscarriage 14 = respiratory disorder 15 = sudden death in adults 16 = sudden death in calves 17 = gradual weight loss and weakness -77 = other, specify below [_____]	1= 1st herd 2= 2nd herd 3= the 2 herds -77 = other, specify below [_____]

2.9.2. Fill the table below in relation to animal health care service providers and product suppliers

Animal health care service provider	Animal health care product supplier

Who is the main and the 2nd provider? (code a)	Overall rating of service (code b)	Main problem (code c)	Who is the main and the 2nd provider? (code d)	Overall rating of service (code b)	Main problem (code e)
1.					
2.					

Main health care service provider (code a)	Problem with service provider (code c)	Main health care product supplier (code d)	Main problem with product supplier (code e)
1 = self 2 = other farmers / neighbours / friends 3 = private veterinarian 4 = government veterinarian 5 = community animal health worker 6 = traditional practitioner 7= NGO staff -77 = other, specify below [_____]	0= no problem 1 = located too far from farm 2 = take too long to respond 3 = not always available 4 = not always competent 5 = too expensive 6 = does not offer services on credit -77 = other, specify below [_____]	1 = market 2 = agrovet store in the village 3 = agrovet shop out of the village 4 = pharmacy for human medicines 5 = Veterinarians or community animal health worker 6 = cooperative 7 = hawker -77 = other, specify below [_____]	0= no problem 1 = located too far from farm 2 = products not always available 3 = products of poor quality 4 = too expensive 5 = does not supply products on credit -77 = other, specify below [_____]

Rating of service provider (code b):

1 = very poor, 2 = poor, 3 = reasonable, 4 = good, 5 = very good

2.10 Feeding and watering practices

2.10.1 Feeding practices

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Complete the following in relation to feeding of the dairy animals over the last 2 years

Feed-type / source	If stover, indicate crop types (code a, list all that apply)	Feed used in dry season (tick if yes)	Feed used in wet season (tick if yes)	For feeds that are used in either dry or wet season		For which herd (code d)
				Source (code b)	Feeding style (code c)	
Natural pasture – grazed in-situ						
Natural pasture – cut and fed fresh						
Natural pasture – cut and stored dry (hay)						
Natural pasture – cut and preserved as silage						
Crop stover – grazed in situ	[___] [___] [___] [___]					
Crop stover – cut and fed fresh (green stover)	[___] [___] [___] [___]					
Crop stover – cut and fed dry (dry stover)	[___] [___] [___] [___]					

Crop stover – cut and conserved as silage	[___] [___] [___] [___]					
Crop – cut and conserved dry, whole	[___] [___] [___] [___]					
forage						
Forage from other crops						
Groundnut cake						
Homemade concentrate rations						
Purchased concentrate						
Rice bran						
Millet bran						
Other brans						
Maize flour						
Groundnut husk						
Bale of millet						
Mineral lick / block						
Card-board / paper						
Other, specify below [_____]						
Other, specify below [_____]						

Other, specify below [_____]						

Stover type (code a)	Source (code b)	Feeding style (code c)	For which herd (code d)
1 = maize or corn stover 2 = millet stover 3 =Sorghum stover 4 = rice straw 5 = millet straw 6 = bean haulms 7 = hay 8 = bean haulms 9 = goundnut haulms 10 = haulms -77 = other, specify below [_____]	1 = on own farm 2 = on another farm, used for free 3 = on another farm, paid for 4 = communal - accessed for free 5 = communal - paid for 6 = purchased from feed supplier -77 = other, specify below [_____]	1 = group feeding of all animals on farm 2 = group feeding of categories of animals (e.g. milk / non-milking, or by breed-type) 3 = individual feeding of all animals 4 = mix of group and individual feeding	1= 1st herd 2= 2nd herd 3= the 2 herds -77 = other, specify below [_____]

2.10.2 Watering practices

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Complete the following in relation to water availability and watering practices over the last 5 years

	How frequently are cattle watered (code a)	Availability of water (code b)	Water sources commonly used (code c, list all that apply)	For which herd? (code d)
Dry season			[___] [___] [___] [___] [___]	
Wet season			[___] [___] [___] [___] [___]	

Frequency of watering (code a)	Availability of water (code b)	Water sources (code c)	For which herd (code d)
1 = one times daily 2 = two times daily 3 = three times daily 4 = More than three times a day 5 = throughout the day -77= other, specify below [_____]	1 = scarce, rare 2 = readily available but far 3 = readily available but expensive 4 = readily available, neither far nor expensive -77 = other, specify below [_____]	1 = well off-farm 2 = well on farm 3 = river / stream off-farm 4 = river / stream on farm 5 = dam on farm 6 = dam off-farm 7 = tapped water on farm 8 = tapped water off-farm 9 = drilled, bore hole -77 = other, specify below [_____]	1= 1st herd 2= 2nd herd 3= the 2 herds -77 = other, specify below [_____]

2.10.3 Feed shortage

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

2.10.3.1 Complete the following in relation to feed shortages

Have you experienced a shortage of dairy feed in the last 5 years? (0=no, 1=yes)	If a feed shortage occurred in the last 5 years, what strategies did you use to manage this (code a, list all that apply)	What strategies do you use to preserve feed during difficult period? (code b, list all that apply)	What months of the year is feed shortage the most problematic (tick those which apply)	
	[___] [___] [___] [___] [___] [___] [___] [___] [___]	[___] [___] [___] [___] [___] [___] [___] [___] [___]	January [__] February [__] March [__] April [__] May [__] June [__]	July [__] August [__] September [__] October [__] November [__] December [__]

Strategies for feed shortages (code a)	Strategies for feed preservation (code b)
1 = none 2 = transhumance - move animals and household to another grazing area 3 = transhumance – move animals only to another grazing area 4 = reduce herd size by selling of cross-bred (indigenous x exotic) or exotic animals 5 = reduce herd size by selling of local / indigenous animals 6 = use feed that had been preserved on farm 7 = graze animal on area that had been preserved on farm 8 = graze animal in area that had been preserved by community 9 = purchase feed off-farm 10 = feed less to animals	1 = none 2 = cut, dry and store natural pastures as loose hay 3 = cut, dry and store crop residues 4 = produce and conserve as silage 5 = purchase dried natural pastures and store as loose hay 6 = purchase and store dried crop residues 7 = purchase silage -77 = other, specify below [_____]

11 = other (conventional and non-conventional feeds, specify below [_____] -77 = other, specify below [_____]	

2.11 Animal housing

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Complete the following table in relation to housing of dairy animals, for each dairy herd (cross-check with section 2.3 on the total number of herds)

Herd number	Cattle breed-type (code a)	Dry season			Rainy season		
		Main mode of housing (code b)	Frequency of housing (code c)	Animal type prioritized (code d)	Main mode of housing (code b)	Frequency of housing (code c)	Animal type prioritized (code d)
1	[____] [____] [____]						

Cattle breed type (code a)	Mode of housing (code b)	Frequency of housing (code c)	Animal prioritisation (code d)
1 = local / indigenous 2 = cross-breed (between local and exotic) 3 = exotic	0 = none 1 = tethered in an open space 2 = ropped off area, no roof 3 = permanently fenced area, no roof 4 = structure with roof 5 = structure with walls and roof (e.g. shed) 6 = in the house -77 = other, specify below [_____]	0 = never 1 = all the time 2 = night only 3 = occasionally / when need arises (e.g. mating, sick, rain) 4 = other, specify below [_____]	1 = no prioritisation 2 = cross-bred or exotic animals 3 = lactating or pregnant females 4 = young animals, including calves 5 = males under fattening 6 = sick / emaciated animals -77 = other, specify below [_____]

2.12 Record keeping and animal identification

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

2.12.1. Fill the following on record keeping and animal identification in relation to the dairy animals

Animal type	Type of records kept (code a)	What type of written records are kept (code b – write all that apply)	Animal identification method (code c – write all that apply)
Local		[____] [____] [____] [____] [____] [____] [____]	[____] [____] [____] [____] [____]
Cross-bred (between local and exotic) or		[____] [____] [____] [____] [____] [____] [____]	[____] [____] [____] [____] [____]
exotic		[____] [____] [____] [____] [____] [____] [____]	[____] [____] [____] [____] [____]
Type of records kept (code a)		Type of written records kept (code b)	Animal identification method (code c)
1 = no records 2 = mental records only 3 = written as well as mental records 4 = written records only 5 = unsure		1 = no written records 2 = pedigree records (sire, dam) 3 = records in relation to AI (when inseminated etc.) 4 = records in relation to natural mating (when put to bull etc.) 5 = birthing records 6= mortality records 7 = animal health records 8 = sales records 9 = visitor or extension officer records -77 = other, specify below [_____]	1 = no identification 2 = names 3 = ear tag 4 = branding / notching / tattooing 5 = coat colour -77 = other, specify below [_____]

2.13 Information and training on dairy

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Fill in the following in relation to information providers on dairy, training received in the last 12 months, and training needs

Main two information providers on dairy (code a)	Training on dairy received in the last 12 months			
	Training received (code b)	Who received the training (code c)	Number of days of training	Top two training needs (code b)
[____] [____]				[____] [____]

Information on dairy (code a)	Training or training needs (code b)	Who received training (code c)
1 = no-one 2 = another smallholder, friend, neighbour 3 = government extension officer 4 = veterinarian or animal health-care worker 5 = NGO 6 = Radio ad other media 7 = cooperative -77 = other, specify below [_____]	1 = no training or no training need 2 = animal health 3 = milking and milk hygiene 4 = animal feeding 5 = keeping of cross-breed / exotic animals 6 = in relation to reproduction, such as heat detection 7 = milk processing 8 = marketing of milk / milk products -77 = other, specify below [_____]	1 = household male 2 = household female 3 = joint household male and household female 4 = non-household member

2.14 Co-operatives or groups on dairy

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Does a member (or more than one member) of the household belong to a diary production cooperative, association or group? (0=no, 1=Yes)

If yes, fill table 2.14.1 below

If no, fill table 2.14.2 below

2.14.1 Fill the following in relation to any dairy co-operatives or groups that household members currently belong to

Name of co-operative or group	Services utilised (code a, list all that apply)	Annual member-ship fee for house-hold	Who pays the member-ship fee? (code b)	Number of household members belonging to group (put zero if needed)		Was this group joined due to the keeping of cross-bred / exotic dairy animals (0=no, 1=yes)
				Men	Women	
	[__] [__] [__] [__]					

Services utilised (code a)	Who paid the membership fee (code b)
1 = collect and sale of milk2 = training of farmers 3= sale of inputs such as animal feed 4= out money together to buy inputs 5=contribution between farmers (to buy parent stock for example) 6=Lobbying, to improve on the livelihood of farmers -77 = other, specify below [_____]	1 = female household member 2 = male household member 3 = jointly between female and male household member 4 = non-household member 5 = unsure

2.14.2 Reason for household members not joining a cooperative, association or groups of dairy producers

Reason	[__] [__] [__]
(Code)	
1=Do not know any cooperative association or group of dairy producers 2= registration fees or contributions are high 3=advantages of becoming a member are unknown 4=was a member before but stopped -77 = other, specify [_____]	

2.15 Constraint to dairy enterprise

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Indicate the three main constraints in relation to the dairy enterprise

Primary constraint (code a)	Secondary constraint (code a)	Tertiary constraint (code a)

Constraint (code a)		
0= no constraint 1 = lack of feed 2 = high cost of feed 3 = lack of labour 4 = high cost of labour 5 = lack of access to AI / good breeding animals 6 = high cost of AI / good breeding animals	7 = animal health problems 8 = cross-breeds / exotics are difficult to keep 9 = low price for milk and milk products 10 = unable to sell all products produced 11 = no access to credit	12 = no access to information 13 = no space to start up a dairy cattle farm 14 = animal theft 15 = I do not know 16 = problem with marketing of milk 17 = problem with capacity building -77 others (Specify) [_____]

2.16 Responsibility in relation to dairy

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Fill the following in relation to who has different responsibility on dairy activities, and who pays for expenses, or controls income. If an activity is not carried out in the household, indicate = -99 in the column "main decision maker". If the household has more than one herd, fill the table for the FIRST Herd Only (the one close to the house)

Activity	Main decision maker	Main labourer	Who pays for expenses associated with this activity	Who controls the income associated with this activity
Feeding of animals				
Watering of animals				
Health-care of animals				
Breeding of animals (when an animal is mated, who the animal will be mated to, whether AI is used)				
Purchase of new animals				
Milking of animals (frequency, when to stop etc.)				
Processing of milk (whether to process, what to process into)				
Membership of groups, such as dairy co-operatives		(do not fill)		(do not fill)

Hire of labourers				
Sale of milk / processed milk products			(do not fill)	
Sale of live animals				
Sale of manure (leave row blank if manure is not sold)				
Training on dairy		(do not fill)		(do not fill)

Codes	
1 = unsure 2 = male household adult (> 15 years) 3 = female household adult (> 15 years) 4 = jointly between male and female household adults 5 = male household child (<15 years) 6 = female household child (<15 years) 7 = jointly between male and female household children	8 = any household member 9 = non-household member such as relative, friend, neighbour 10 = hired male labourer 11 = hired female labourer -77 = other, specify below [_____]

2.19. Source of water and electricity to the farm

Respondent: farmer (owner) [____] other member of the family [____] or herder (labour) [____]

Source of electricity (code a)	Source of water (code b)
Source of electricity (code a)	Source of water (code b)
1=no electricity 2=electricity from the national electricity company only 3=electricity from other sources (generators, solar cells) 4 = electricity from national electricity company and other sources	1 = piped water to and farm, available and working 2 = no piped water to farm

3.0 INFORMATION ON THE HOUSEHOLD

This section should be filled by the farmer (household head or spouse). If she is not available, please give reason (s) _____

3.1 People living in household

Fill the table in relation to people who were present in the household for at least three months during the past 12 months. Include the household head, all the members of the family and non-member of the household.

gender and Age categories	Number of household members	Number of non-household members
Girls 0-<2 years		
Boys 0-<2 years		
Girls 2-<10 years		
Boys 2-<10 years		
Girls 10-<18 years		
Boys 10-<18 years		
Women 18-<60 years		
Men 18-<60 years		
Women 60 years and above		
Men 60 years and above		

3.2 What is the highest educational level of the household head? [____]

Highest level of education
0=No formal and illiterate 1=No formal but literate 2= Primary school 3= High / secondary school 4= College 5= University 6 = Koranic school -77= Other (specify) [_____]

3.3 Indicate the household religion and ethnic group

Main household religion (code a)	Main household ethnic group (code b)
Religion (code a)	Ethnic group (code b)

1 = No religion 2 = Christian 3 = Muslim 4 = Traditional -77 = other, specify below [_____]	1 = Fula (Peul) 2 _= Serere 3 = Wolof 4 = Mandinka 5 = Jola -77 = other, specify below [_____]

3.4 Household assets

3.4.1 Indicate the following in relation to household land assets

Parcel of land	Size of land parcel	Unit associated with size of land parcel (code a)	Tenure system (code b)	If parcel is owned, who owns (code c)	Purchase price if owned (write 0 if obtained for free, such as a gift)	Annual rental price if rented	Land used for dairy (code d, list all that apply)	Was this land acquired specifically in relation to keeping cross-bred / exotic animals (0=no, 1=yes)
1							[__] [__] [__] [__]	

a. Unit of Land	b. Tenure system	c. If owned, name on title or certificate	d. Land used for dairy
1 = cubic metres 2 = hectare -77 = others, specify below including conversion to metric system [_____]	1 = occupancy permit 2 = title deed 3 = owned but not titled 4 = public land 5 = rented-in 6 = sharecropped -77 = other, specify below [_____]	1 = male household member 2 = female household member 3 = jointly between male and female household member 4 = relative not living in household 5 = other from outside the household	1 = not used for dairy 2 = used for grazing of dairy animals 3 = used for growing other feed for dairy animals (besides natural pastures) 4 = used for housing dairy animals -77 = other use for dairy, specify below [_____]

3.2.2. Fill the following in relation to household livestock assets, other than dairy cattle (which were listed in section 2.3.1). Count all animals, whether young or adult.

Livestock species			Number of animals owned			
			By male	By female	Jointly	Total
Cattle, non-dairy	Local	Bull				
		Castrated males				
		Cow				
		Immature males/ heifers				
		Calves				
	Cross-bred or exotic	Bull				
		Castrated males				
		Cow				
		Immature males/ heifers				
		Calves				
Goats	Local					
	Cross-bred or exotic					
Sheep	Local					
	Cross-bred or exotic					
Poultry	Local					
	Cross-bred or exotic					
Pigs	Local					
	Cross-bred or exotic					
Donkeys						
Horses						
Rabbits						
Other, specify below [_____]						
Other, specify below [_____]						

3.4 Livelihood sources and income

3.4.1 What are the 3 main sources of livelihood for this household over the last 12 months

Primary livelihood source	Secondary livelihood source	Tertiary livelihood source

Codes

0 = nothing

1 = food crop production (both own consumption and sale e.g. gardening, fruits, vegetable production)

2 = cash crop production (e.g. coffee, cotton, sisal etc.)

3 = animal feed and fodder production

4 = beef cattle keeping

5 = dairy cattle keeping

6 = sheep and goat keeping

7 = poultry keeping

8 = working for someone on another farm

9 = own business related to livestock or agriculture (such as livestock trader, feed supplier, agricultural extension)

10 = own business not related to livestock or agriculture

11 = formal salaried employment (non-farming)

12 = rent out land / sharecropping (cash value of rent or share crop)

13 = remittances

14 = pension

-77 = other, specify below

[_____]

3.4.2 Fill the following in relation to household income

What is the household's average monthly income? (code)	
Estimated percentage of monthly household income from dairy (%)	

Codes

1 = less than 15,000 FCFA (30 USD) per month

2 = 15,000 to 30,000 FCFA (30 to 60 USD) per month

3 = 30,000 to 60,000 FCFA (60 to 120 USD) per month

4 = 60,000 to 120,000 FCFA (120 to 240 USD) per month

5 = greater than 120,000 FCFA (240 USD) per month

3.4.3 Fill the following in relation to savings and credit over the last 12 months

Savings means (code a, indicate all that apply)	Credit applied for over the last 12 months, by a household member			
	What type of credit was applied for (code b)	Amount of credit applied for	Who applied for the credit (code c)	Was the credit received (0=no, 1=yes)
[____] [____] [____]				

Saving means (code a)	Credit (code b)	Who applied for credit (code c)
1 = no means to save 2 = savings groups 3 = investment in livestock 4 = kept in compound -77 = other, specify below [_____]	1 = no credit 2 = credit to support the dairy enterprise 3 = credit to support other farm activities 4 = credit for food 5 = credit for education 6 = credit to improve house -77= other, specify below [_____]	1 = male household member 2 = female household member 3 = jointly between female and male household member -77= other, specify below [_____]

3.3.4. Indicate the importance of dairy as a household livelihood activity now in comparison to 10 years ago?

Importance of dairy to household now, in comparison to 10 years ago	
Codes	
1 = less important now than 10 years ago 2 = same importance as 10 years ago 3 = more important now than 10 years go	

3.3.5. Complete the following in relation to household electricity, water, and insurance

Household insurance taken out in last 12 months (code c, list all that apply)
[___] [___] [___] [___] [___][___]
Insurance (code c)

1 = no insurance 2 = health insurance 3 = home / domestic insurance 4 = crop insurance 5 = livestock insurance -77 = other, specify below [_____]

End of Questionnaire:

Thank the respondent. Ask her if she has questions for you. Explain that you will come in a few weeks' time.

Time interview ended:	HH:	MM:

Quality Assurance Aspects

<u>Enumerator</u>: enter your comments here AFTER you have administered the questionnaire

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Appendix 1(c) . Household head cattle breed and trait preferences questionnaire

This questionnaire should be filled out with the wife (or first wife in polygamous households) or other adult female knowledgeable about household livelihood activities and food consumption. If need be, you will need to ask some questions to the other women.

1. GENERAL INFORMATION

Date of survey (DD/MM/YYYY)		
Enumerators name		
Head of household name		
Time interview started:	HH:	MM:
Information on site and household		
Site name		
Village name		
Name of survey respondent		
Relationship of respondent to household head (code a)		
Is this the same respondent as for the 'baseline household head' survey (0=no, 1=yes)		
Household ID (code b)	[___AF_____] [_____] [_____] Survey-type site household	
Respondent relationship (code a)	Household ID (code b)	
1 = household head 2 = wife / spouse 3 = other family member 4 = other non-family member	Survey type AF = adult female baseline Site code 1 = Thies / Tivaouane 2 = Touba /Mbacke	

2. INFORMATION ON THE DAIRY PRODUCTION SYSTEM

If the respondent is the same as for the 'baseline household head' survey, then go to Q3

2.1 Dairy breed-types

2.1.1 Does the respondent know more than one cattle breed-type? (0=non, 1= yes)
[_____]

If no, go to the next question.

If yes, fill the table below relation to the most and least preferred breed-type

2.1.2 What are the cattle breed types owned, managed or known by the respondent?

- Local breeds: [___] [___]; [___] [___]; [___] [___]
- Cross breeds: [___] [___]; [___] [___]; [___] [___]
- Exotic breeds: [___] [___]; [___] [___]; [___] [___]

Breed-type	Preference code (code a)	Reason for preference, indicate all (code b)	Inconvenience, indicate all (code c)
Local breeds (pure)			
Cross breeds			
Exotic breeds (pure)			

Preference (code a)	Reason for preference (code b)	Inconvenience (code c)
1 = high preference 2= moderate preference 3= low preference 4= indifferent	0= no particular reason 1 = high milk yield 2 = good milk quality 3 = high sale value of calves 4 = well adapted to local conditions 5 = good disease resistance 6 = easy to manage 7 = low feed intake 8 = good reproductive rates 9 = low calf mortality 10 = nice coat colour 11 = adequate conformation of the udder 12 = weight and conformity of the animal	0= no inconvenience 1 = low milk yield 2 = poor milk quality 3 = low sale value of calves 4 = poorly adapted to local conditions 5 = poor disease resistance 6 = hard to manage 7 = high feed intake 8 = poor reproductive rates 9 = high calf mortality 10 = bad skin colour 11= inadequate shape and size of the udder

	13 = fast growth 14 = adapted to long to walk -77 = other, specify below [_____]	12= inadequate weight and conformity of the cow 13 = poor growth rate 14 = not adapted to long walk -77 = other, specify below [_____]

2.2 Constraints to dairy

Indicate the three main constraints in relation to the dairy enterprise

Primary constraint (code a)	Secondary constraint (code a)	Tertiary constraint (code a)
Code a		
0= no constraint 1 = lack of feed 2 = high cost of feed 3 = lack of labour 4 = high cost of labour 5 = lack of access to AI / good breeding animals 6 = high cost of AI / good breeding animals	7 = animal health problems 8 = cross-breeds / exotics are difficult to keep 9 = low price for milk and milk products 10 = unable to sell all products produced 11 = no access to credit	12 = no access to information 13 = no space to start up a dairy cattle farm 14 = animal theft 15 = I do not know 16 = problem with marketing of milk 17 = problem with capacity building -77 others (Specify) [_____]

2.3 Responsibilities in relation to dairy farming

Fill the following in relation to who has different responsibility on dairy activities, and who pays for expenses, or controls income. If one activity does not apply, indicate 99 in the column "Main decision maker". If the household has more than one herd, fill the table for the first herd only (the one close to the house)

Activity	Main decision maker	Main labourer	Who pays for expenses associated with this activity	Who controls the income associated with this activity
Feeding of animals				

Watering of animals				(do not fill)
Health-care of animals				
Breeding of animals (when an animal is mated, who the animal will be mated to, whether AI is used)				
Purchase of new animals				
Milking of animals (frequency, when to stop etc.)				
Processing of milk (whether to process, what to process into)				
Membership of groups, such as dairy co-operatives		(do not fill)		
Hire of labourers				
Sale of milk / processed milk products			(do not fill)	
Sale of live animals				
Sale of manure (leave row blank if manure is not sold)				
Training on dairy		(do not fill)		(do not fill)

Codes	
1 = unsure	8 = any household member
2 = male household adult (> 15 years)	9 = non-household member such as relative, friend, neighbour
3 = female household adult (> 15 years)	10 = hired male labourer
4 = jointly between male and female household adults	11 = hired female labourer
5 = male household child (<15 years)	-77 = other, specify below
6 = female household child (<15 years)	[_____]
7 = jointly between male and female household children	

Training needs in relation to dairy

Indicate the top two training needs in relation to dairy

Top two training needs (code a)

[____] [____]	
Training needs (code a)	
1 = no training 2 = animal health 3 = milking and milk hygiene 4 = animal feeding 5 = keeping of cross-breed / exotic animals	6 = in relation to reproduction, such as heat detection 7 = milk processing 8 = marketing of milk / milk products 9 = other, specify below [_____]

3. INFORMATION ON THE HOUSEHOLD

3.1. Household assets

3.1.1. Fill the following in relation to main house

Home ownership (code a)	Number of rooms	Floor material (code b)	Wall material (code c)	Roofing material (code d)

Home ownership (code a)	Floor material (code b)	Wall material (code c)	Roofing material (code d)
1 = owned 2 = rented 3 = borrowed (no taxes) -77 = other, specify below [_____]	1 = earth 2 = cement 3 = tiles 4 = earth and cement 5 =earth and tiles 6 = cement and tiles -77= other, specify below [_____]	1 = earth / mud 2 = wood / bamboo / iron sheets 3 = cement / bricks 4 = earth/mud and wood / bamboo / iron sheets 5 = earth/mud and cement / bricks 6 = wood / bamboo / iron sheets and cement / bricks -77= other, specify below [_____]	1 = grass 2 = iron sheet / asbestos 3= cement 4 = tiles / slates 5 = grass and iron sheet / asbestos 6 = grass and cement 7 = iron sheet / asbestos and cement -77= other, specify below [_____]

3.1.2. Fill the following in relation to household farm and domestic assets

Asset name		Numbers by ownership and age of asset

	Total number	Owned by men			Owned by women			Jointly owned		
		< 3 years	3-7 years	>7 years	< 3 years	3-7 years	>7 years	< 3 years	3-7 years	>7 years
Domestic										
Cooker / gas stove										
Refrigerator										
Radio										
Television										
DVD player										
Mobile phone										
Sofa set										
Sewing machine										
Mosquito nets										
Air conditioner										
Transport										
Car / Truck										
Motorcycle										
Bicycle										
Cart (animal drawn)										
Farm										
Small equipment (Hoes, spades, rake etc)										
Ploughs										
Sprayer pump										
Water pump										
Automated milker										

Electric generator										
Fan										
Other, specify below [_____]										

Where it is possible all women should participate in the questionnaire. If this not possible, the enumerator should mention as a comment.

3.2 Livelihood activities and income

3.2.1. What are the 3 main sources of livelihood for this household over the last 12 months, that female household members have been involved in

Primary livelihood source	Secondary livelihood source	Tertiary livelihood source
Codes		
0 = nothing or no control or checks on household income 1 = food crop production (both own consumption and sale e.g. gardening, fruits, vegetable production) 2 = cash crop production (e.g. coffee, cotton, sisal etc.) 3 = animal feed and fodder production 4 = beef cattle keeping 5 = dairy cattle keeping 6 = sheep and goat keeping 7 = poultry keeping 8 = working for someone on another farm	9 = own business related to livestock or agriculture (such as livestock trader, feed supplier, agricultural extension) 10 = own business not related to livestock or agriculture 11 = formal salaried employment (non-farming) 12 = rent out land / sharecropping (cash value of rent or share crop) 13 = remittances 14 = pension -77 = other, specify below [_____]	

3.2.2. Fill the following in relation to dairy related income

How much of the total annual income from dairy (sale of dairy products, sale of animals etc.) is controlled by household females (%)	
What is this dairy related income mainly spent on – give the three main expense types (code)	[_____][_____] [_____]
Codes	

1 = food for the household	5 = dairy farm activities
2 = school fees	6 = other farm activities
3 = health care (human)	7 = non-farm activities (such as other business)
4 = other household expenses	8 = other, specify below [_____]

4. HOUSEHOLD FOOD SECURITY

4.1. Household diet and adequacy of food provisioning

Fill the below in relation to household diet

Types of foods	In the last 24 hours, have you consumed these? (0=no, 1=yes)	In the last 7 days, how many days have you consumed these?
Staples or food made from staples including millet, sorghum, maize, rice, wheat, or other local grains, e.g. bread, rice, noodles, biscuits, or other foods		
Potatoes, yams, cassava or any other foods made from roots or tubers		
Vegetables		
Fruits		
Beans, peas, lentils, or nuts?		
Red meat-beef, pork, lamb, goat, rabbit wild game, liver, kidney, heart, or other organ meats?		
Poultry including chicken, duck, other poultry		
Eggs		
Fresh or dried fish or shellfish?		
Milk, cheese, yogurt, or other milk product		
Oils and fats?		
Sweets, sugar, honey		
Any other foods, such as condiments, coffee, tea including milk in tea?		

4.2. Indicate the months where the household food was adequate

In the last 12 months, did you have enough food to eat during all the months? (0=no, 1=yes)	
If no, which were the months in the last 12 months that you did have enough food to meet your family's needs Do not read the list of months. Work backwards from the current month, and place a '1' next to the month if the respondent indicate that was sufficient food to meet household needs in that month	January [_____] July [_____] February [_____] August [_____] March [_____] September [_____] April [_____] October [_____] May [_____] November [_____] June [_____] December [_____]

Head of household name	HH:	MM:

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